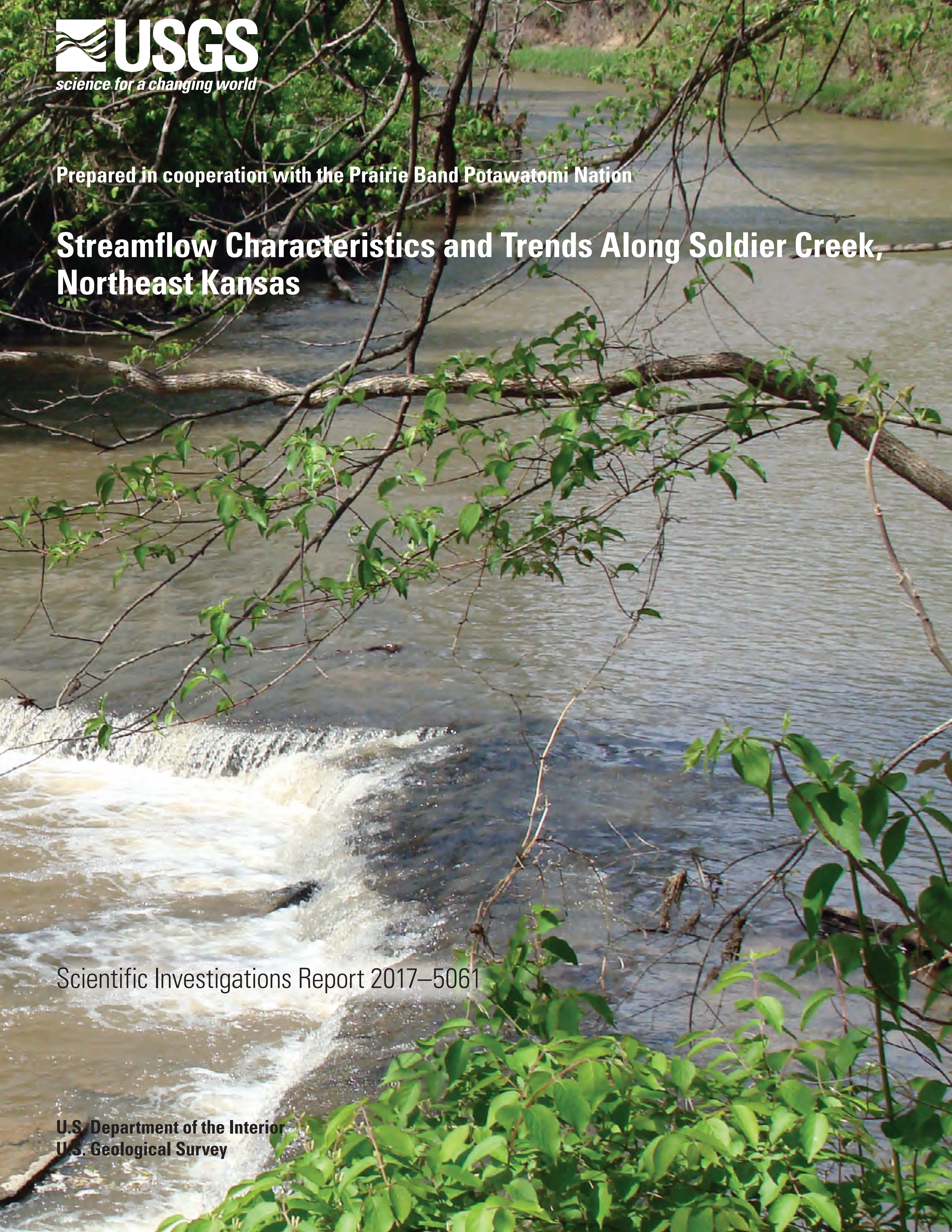

USGS
science for a changing world

Prepared in cooperation with the Prairie Band Potawatomi Nation

Streamflow Characteristics and Trends Along Soldier Creek, Northeast Kansas

Scientific Investigations Report 2017–5061

U.S. Department of the Interior
U.S. Geological Survey

Cover photograph. Soldier Creek at Rocky Ford, northeast Kansas (photograph taken by Verna Potts, Prairie Band Potawatomi Nation, on April 19, 2017).

Streamflow Characteristics and Trends Along Soldier Creek, Northeast Kansas

By Kyle E. Juracek

Prepared in cooperation with the Prairie Band Potawatomi Nation

Scientific Investigations Report 2017–5061

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
RYAN K. ZINKE, Secretary

U.S. Geological Survey
William H. Werkheiser, Acting Director

U.S. Geological Survey, Reston, Virginia: 2017

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment—visit https://www.usgs.gov or call 1–888–ASK–USGS.

For an overview of USGS information products, including maps, imagery, and publications, visit https://store.usgs.gov/.

Suggested citation:
Juracek, K.E., 2017, Streamflow characteristics and trends along Soldier Creek, northeast Kansas: U.S. Geological Survey Scientific Investigations Report 2017–5061, 30 p., https://doi.org/10.3133/sir20175061.

ISSN 2328-0328 (online)

Contents

Figures

Tables

Appendix Table

Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Streamflow Characteristics and Trends Along Soldier Creek, Northeast Kansas

By Kyle E. Juracek

Abstract

Historical data for six selected U.S. Geological Survey streamgages along Soldier Creek in northeast Kansas were used in an assessment of streamflow characteristics and trends. This information is required by the Prairie Band Potawatomi Nation for the effective management of tribal water resources, including drought contingency planning. Streamflow data for the period of record at each streamgage were used to assess annual mean streamflow, annual mean base flow, mean monthly flow, annual peak flow, and annual minimum flow.

Annual mean streamflows along Soldier Creek were characterized by substantial year-to-year variability with no pronounced long-term trends. On average, annual mean base flow accounted for about 20 percent of annual mean streamflow. Mean monthly flows followed a general seasonal pattern that included peak values in spring and low values in winter. Annual peak flows, which were characterized by considerable year-to-year variability, were most likely to occur in May and June and least likely to occur during November through February. With the exception of a weak yet statistically significant increasing trend at the Soldier Creek near Topeka, Kansas, streamgage, there were no pronounced long-term trends in annual peak flows. Annual 1-day, 30-day, and 90-day mean minimum flows were characterized by considerable year-to-year variability with no pronounced long-term trend. During an extreme drought, as was the case in the mid-1950s, there may be zero flow in Soldier Creek continuously for a period of one to several months.

Introduction

The availability of adequate water to meet the present and future needs of humans, fish, and wildlife is a fundamental issue for the Prairie Band Potawatomi Nation in northeast Kansas. Because Soldier Creek flows through the Prairie Band Potawatomi Nation Reservation (fig. 1), it is an important tribal resource. An understanding of historical Soldier Creek streamflow conditions is required for the effective management of tribal water resources, including drought contingency planning.

To provide some of the information necessary for the future management of tribal water resources, a 1-year study by the U.S. Geological Survey (USGS), in cooperation with the Prairie Band Potawatomi Nation, was begun in 2016 to assess streamflow characteristics at six selected USGS streamgages along Soldier Creek. The assessment provides information on historical streamflow availability, variability, and trends.

Purpose and Scope

The purpose of this report is to present the results of the USGS study to assess streamflow characteristics and trends at six selected USGS streamgages along Soldier Creek in northeast Kansas. Various streamflow characteristics were computed and compared for the period of record for each site, which ranged from water years 1936 through 2015 (80 years) to water years 2001 through 2007 (6 years). Unless otherwise noted, water years are used in the analyses described in this report. A water year is the 12-month period beginning October 1 and ending September 30 that is designated by the calendar year in which it ends.

Results presented in this report will provide some of the information needed by the Prairie Band Potawatomi Nation to enable better informed and more effective management of tribal water resources. Specifically, the assessment provides multidecadal information at multiple sites that will contribute to an improved understanding of historical streamflow conditions along Soldier Creek. Nationally, the methods and results presented in this report provide guidance and perspective for future studies concerned with streamflow characterization and the management implications thereof.

Description of Soldier Creek Basin

The Soldier Creek Basin is an area of about 334 square miles in northeast Kansas (fig. 1). In addition to Little Soldier Creek, other lesser tributaries to Soldier Creek, in downstream order, include Crow Creek, South Branch Soldier Creek, James Creek, Dutch Creek, Walnut Creek, Messhoss Creek, Silver Lake Ditch, Halfday Creek, and Indian Creek (fig. 1). Estimates of streamflow statistics (flow duration, mean flow, peak values) for multiple ungaged sites along Soldier Creek

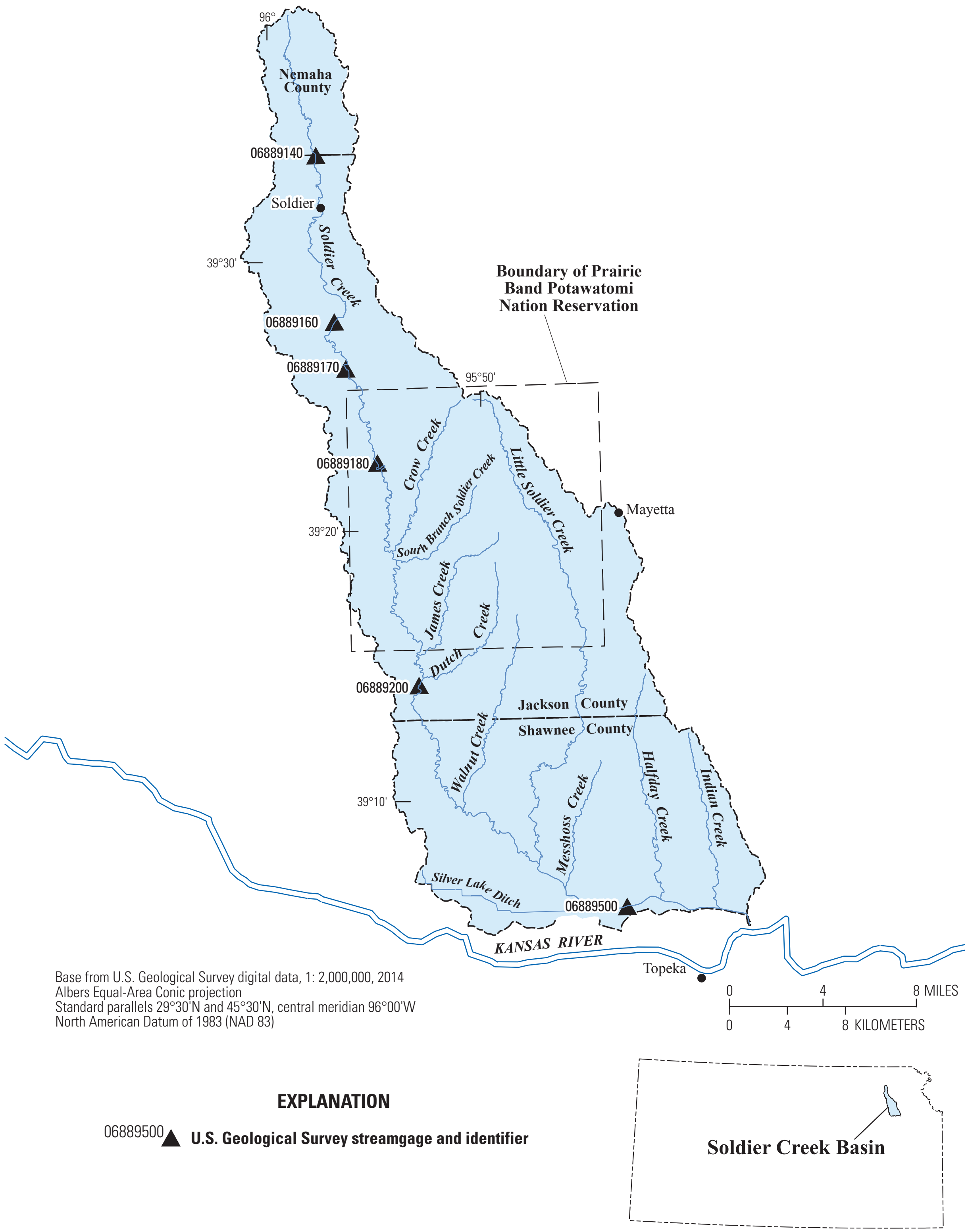

Figure 1. Location of Soldier Creek Basin, Soldier Creek, major tributaries, Prairie Band Potawatomi Nation Reservation, and selected U.S. Geological Survey streamgages, northeast Kansas.

and its tributaries are provided by Perry and others (2004). Land use in the basin mostly is a mix of cropland and grassland (fig. 2) (Jin and others, 2013).

Spatially averaged annual precipitation for the Soldier Creek Basin for calendar years 1951 through 2014, derived from Parameter-elevation Relationships on Independent Slopes Model (PRISM) monthly precipitation data (Daly and others, 2008), was about 35 inches. As shown in figure 3 for the Soldier Creek streamgages near Circleville and Delia, spatially averaged annual precipitation for the subbasins was characterized by substantial year-to-year variability with no apparent long-term trend.

During the 21st century, global warming is projected to result in minimal change in average annual precipitation in Kansas; however, the amount of precipitation in individual storm events may increase (Walsh and others, 2014). An examination of the 50 largest 24-hour precipitation events at Topeka, Kansas, for calendar years 1947 to 2016 (National Centers for Environmental Information, 2017) indicated no apparent trend in the frequency or magnitude of the events.

Methods

Streamflow characteristics and trends were examined for the period of record for six USGS streamgages along Soldier Creek in northeast Kansas (fig. 1, table 1). The available streamflow data used for this study were collected as part of the USGS national streamgaging network using standard USGS methods (Turnipseed and Sauer, 2010). Near real-time and (or) historical streamflow data for the six streamgages are available from the USGS National Water Information System (NWIS) (U.S. Geological Survey, 2016).

For each streamgage, streamflow characteristics were computed for each water year (October 1 to September 30) during the period of record using daily mean streamflow values downloaded from NWIS (U.S. Geological Survey, 2016). Specific streamflow characteristics computed were annual mean streamflow, annual mean base flow, mean monthly flow, annual peak flow, and annual minimum flow (1-day, 30-day, and 90-day means). Annual mean base flow was computed as the average of daily mean base-flow values that were estimated using a base-flow-separation technique as described by Wahl and Wahl (1995). Also, streamflow-duration curves were developed for each site for which a sufficient period of record was available (Flynn and others, 1995; current version available at https://water.usgs.gov/software/SWSTAT/). Streamflow-duration curves show the percentage of time that a streamflow of specific magnitude is equaled or exceeded during the period of record analyzed.

Trends were assessed by computing the coefficient of determination (R^2) and *p*-value from linear regression analysis using Microsoft Excel® software (2016 version). The R^2 indicates the extent to which a dependent variable can be predicted by an independent variable using regression. The R^2 values range from 0, which indicates that none of the variance is explained, to 1, which indicates that all of the variance is explained. In this report, an R^2 value greater than 0.5 is considered a strong relation, 0.25 to 0.5 a moderate relation, and less than 0.25 a weak relation. The *p*-value indicates the statistical significance of a trend. The *p*-value is a probability that measures the "believability" of the null hypothesis (in this case, no trend). The smaller the *p*-value, the greater the evidence for rejection of the null hypothesis (Helsel and Hirsch, 1992). In this study, a trend was considered statistically significant if the *p*-value was less than or equal to 0.05.

Streamflow Characteristics and Trends

In this section, results of the streamflow analyses for the six selected streamgages are presented in downstream order. Topically, the order of presentation is annual mean streamflow, annual mean base flow, mean monthly flow, annual peak flow, annual minimum flow, and streamflow-duration curves. Given the short period of record (2001 to 2007) for the Soldier Creek near Holton, Kansas, streamgage (06889170), the results of the streamflow assessment for that site may not be representative of long-term conditions and therefore are presented with no discussion. Unless otherwise stated, trends assessed in this study were weak (typically, R^2 less than 0.10) and not statistically significant (*p*-value greater than 0.05) and described as no pronounced trend.

Table 1. Six U.S. Geological Survey streamgages along Soldier Creek, northeast Kansas, used in this study to examine streamflow characteristics and trends.

[USGS, U.S. Geological Survey; mi^2, square mile]

USGS streamgage identifier (fig. 1)	USGS streamgage name	Drainage area (mi^2)	Period of record
06889140	Soldier Creek near Soldier, Kansas	17	1964–1998
06889160	Soldier Creek near Circleville, Kansas	49	1964–2001
06889170	Soldier Creek near Holton, Kansas	61	2001–2007
06889180	Soldier Creek near Saint Clere, Kansas	80	1964–1981
06889200	Soldier Creek near Delia, Kansas	157	1958–2015
06889500	Soldier Creek near Topeka, Kansas	290	1936–2015

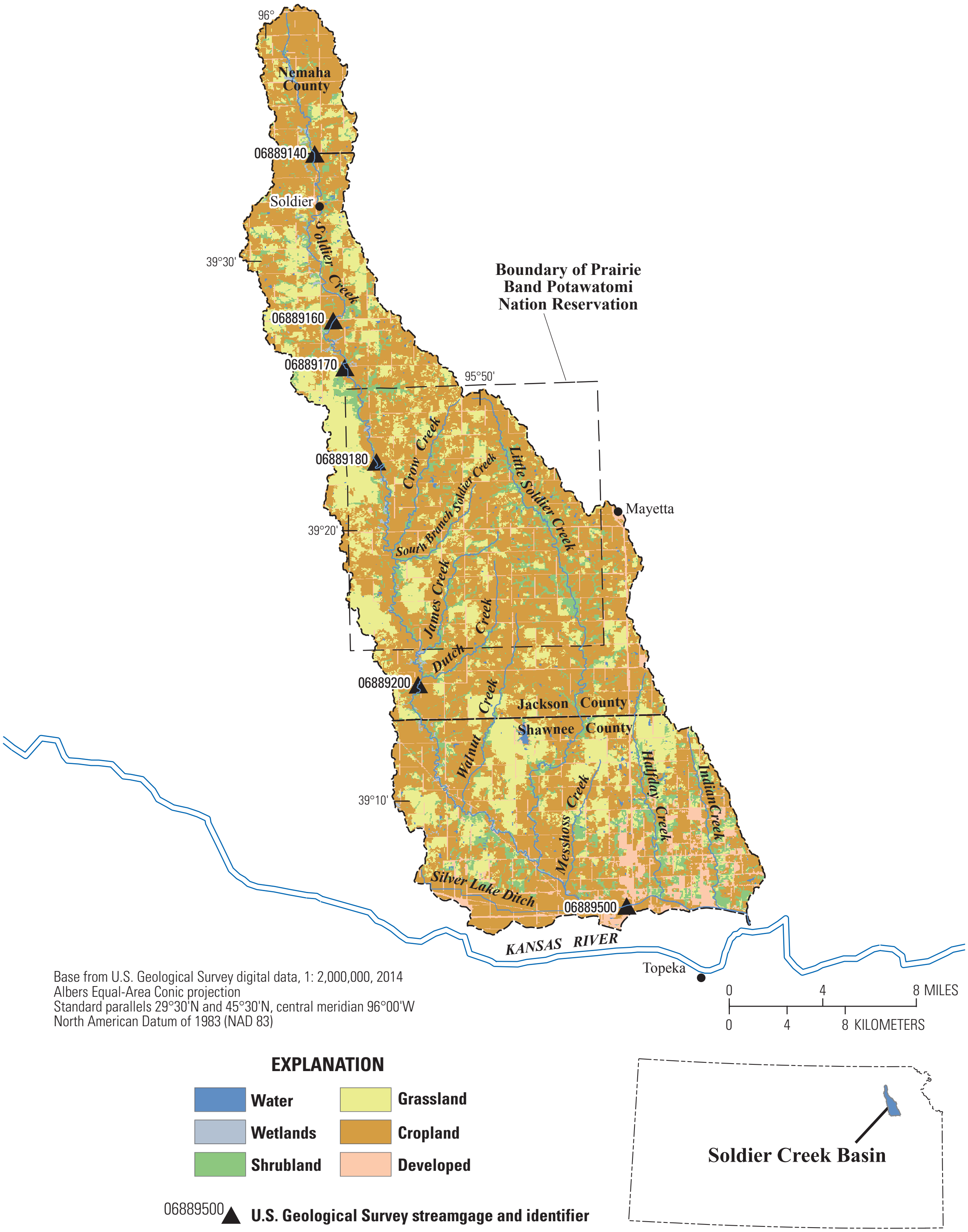

Figure 2 Land use (2011) in the Soldier Creek Basin.

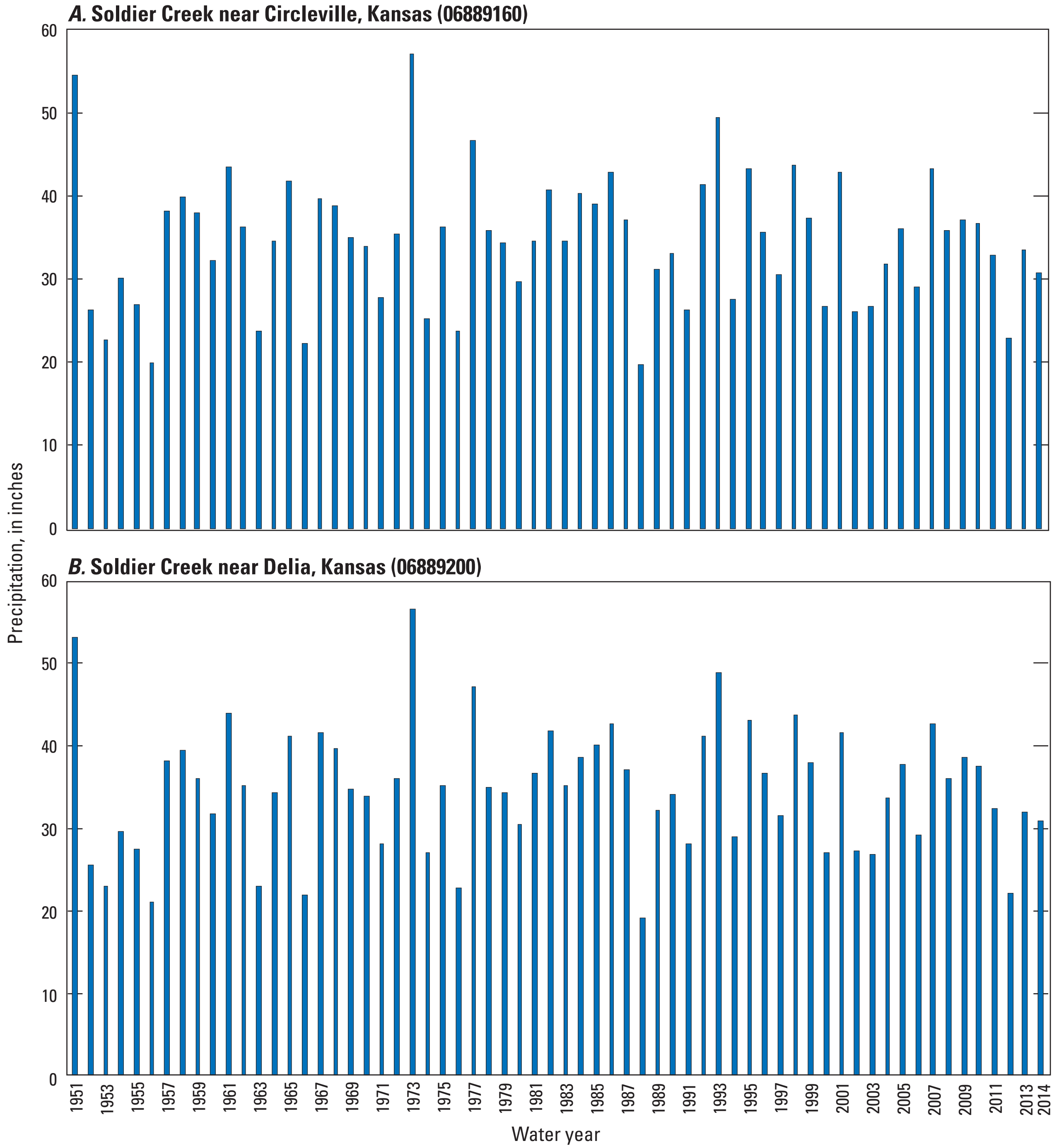

Figure 3. Variation in annual precipitation for the basins of two selected U.S. Geological Survey streamgages. *A*, Soldier Creek near Circleville, Kansas (06889160). *B*, Soldier Creek near Delia, Kansas (06889200). (Source: Daly and others, 2008)

Annual Mean Streamflow

Along Soldier Creek, annual mean streamflow was characterized by substantial year-to-year variability with no pronounced long-term trend (fig. 4). At the Soldier Creek near Soldier, Kansas, streamgage (06889140, fig. 1, table 1) (hereafter referred to as "Soldier"), annual mean flow during the period of record (1964 to 1998) ranged from about 1 cubic foot per second (ft^3/s) in 1991 to about 38 ft^3/s in 1993. Annual mean flow at this site was less than 5 ft^3/s for 8 years (24 percent) of the period of record including 4 consecutive years (1988 to 1991). Conversely, annual mean flow was greater than 25 ft^3/s for 3 years (9 percent) of the period of record (fig. 4*A*).

During the period of record (1964 to 2001) at the Soldier Creek near Circleville, Kansas, streamgage (06889160, fig. 1, table 1) (hereafter referred to as "Circleville"), annual mean flow ranged from about 5 ft^3/s in 1991 to about 90 ft^3/s in 1993. For 6 years (17 percent) of the period of record, annual mean flow was less than 10 ft^3/s. In contrast, for 4 years (11 percent) of the period of record, annual mean flow exceeded 70 ft^3/s (fig. 4*B*).

At the Soldier Creek near Saint Clere, Kansas, streamgage (06889180, fig. 1, table 1) (hereafter referred to as "Saint Clere"), annual mean flow during the period of record (1964 to 1981) ranged from about 14 ft^3/s in 1966 to 135 ft^3/s in 1973. Annual mean flow was less than 20 ft^3/s for 2 years (12.5 percent) of the period of record. Conversely, annual mean flow was greater than 90 ft^3/s for 2 years (12.5 percent) of the period of record (fig. 4*D*).

During the period of record (1958 to 2015) at the Soldier Creek near Delia, Kansas, streamgage (06889200, fig. 1, table 1) (hereafter referred to as "Delia"), annual mean flow ranged from about 19 ft^3/s in 2003 to 281 ft^3/s in 1973. For 6 years (11 percent) of the period of record, annual mean flow was less than 25 ft^3/s. Of the 6 years, 5 years occurred during the period 2000 to 2015 and 3 years occurred consecutively (2012 to 2014). Annual mean flow exceeded 250 ft^3/s for 3 years (5 percent) of the period of record (fig. 4*E*).

At the Soldier Creek near Topeka, Kansas, streamgage (06889500, fig. 1, table 1) (hereafter referred to as "Topeka"), annual mean flow during the period of record (1936 to 2015) ranged from about 5 ft^3/s in 1956 to 590 ft^3/s in 1993. Annual mean flow was less than 40 ft^3/s for 9 years (11 percent) of the period of record. Of the 9 years, 4 years occurred consecutively from 1953 to 1956 and 3 years occurred consecutively from 2012 to 2014. Annual mean flow was greater than 400 ft^3/s for 4 years (5 percent) of the period of record (fig. 4*F*).

To provide a comparison of Soldier Creek flow into and out of the reservation, annual mean flows at Circleville (upstream) and Delia (downstream) were compared for 1965 to 2000 (that is, the period for which complete water year flow data were available for both sites). The comparison indicated an increase in annual mean flow from Circleville to Delia that ranged from about 130 percent (in 1984) to about 610 percent (in 1991) with an average increase of about 240 percent.

Annual Mean Base Flow

On an annual basis, mean base flow typically accounted for a small percentage of the mean streamflow in Soldier Creek (fig. 4). At Soldier, the percentage of the annual mean flow that was annual mean base flow typically ranged between 5 and 25 percent with an average of about 15 percent (fig. 5*A*). At Circleville, the typical range was about 10 to 30 percent with an average of about 18 percent (fig. 5*B*). Downstream at Saint Clere and Delia, the typical ranges were about 15 to 30 percent and 10 to 30 percent, respectively, with an average of about 24 percent (figs. 5*D* and 5*E*). At Topeka, the typical range was about 10 to 30 percent with an average of about 21 percent (fig. 5*F*). Overall, on an annual basis, mean base flow accounted for an average of about 20 percent of mean flow.

Mean Monthly Flow

Along Soldier Creek, a general seasonal pattern for mean monthly flows was evident for the six selected streamgages that was reflective of the seasonal variability in precipitation. Beginning with low flows in January, the mean monthly flows progressively increased to peak values in May or June. Subsequently, mean monthly flows declined in July and August. Following an increase in September, mean monthly flows again declined in October, November, and December (fig. 6).

To provide a comparison of Soldier Creek flow into and out of the reservation, mean monthly flows at Circleville (upstream) and Delia (downstream) were compared for 1964 to 2001 (that is, the period for which monthly flow data were available for both sites). The comparison indicated an increase in mean monthly flow from Circleville to Delia that ranged from about 170 percent (in February) to about 310 percent (in December) with an average increase of about 230 percent (table 2).

Table 2. Comparison of mean monthly flows at the Soldier Creek streamgages near Circleville (06889160) and Delia (06889200), Kansas, for the period 1964 to 2001.

[ft^3/s, cubic foot per second]

Month	Mean monthly flow, in ft^3/s		Percentage increase[1]
	Circleville	Delia	
January	10.2	37.7	270
February	26.6	71.4	170
March	46.2	132.5	190
April	49.1	161	230
May	60.5	185.6	210
June	68.9	212.6	210
July	30.8	96.3	210
August	14	48.6	250
September	28.4	93.1	230
October	19.9	69.3	250
November	20	70.1	250
December	12.1	49.5	310

[1]Percentages rounded to the nearest 10 percent.

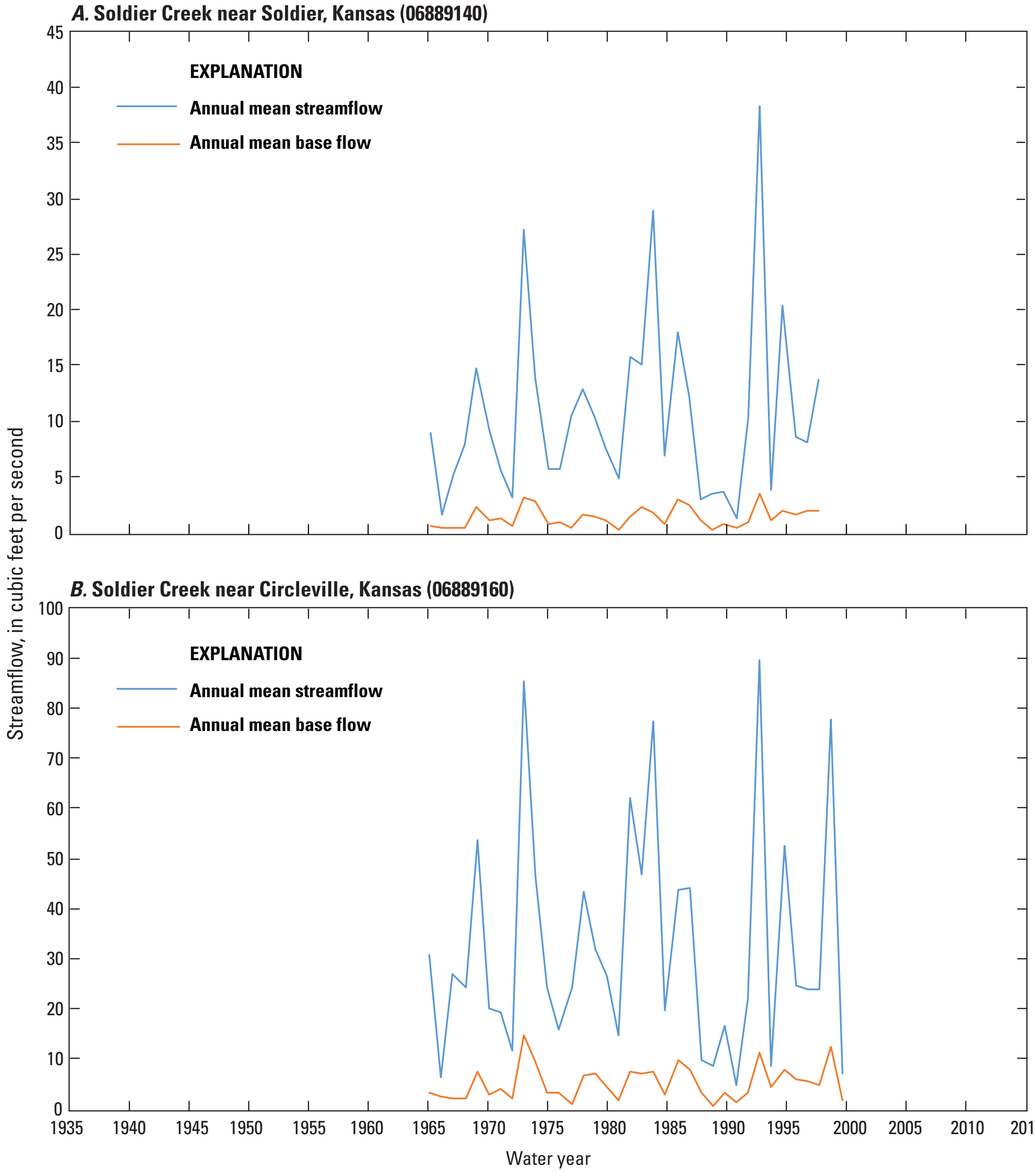

Figure 4. Variation in annual mean streamflow and annual mean base flow at six selected U.S. Geological Survey streamgages. *A*, Soldier Creek near Soldier, Kansas (06889140). *B*, Soldier Creek near Circleville, Kansas (06889160). *C*, Soldier Creek near Holton, Kansas (06889170). *D*, Soldier Creek near Saint Clere, Kansas (06889180). *E*, Soldier Creek near Delia, Kansas (06889200). *F*, Soldier Creek near Topeka, Kansas (06889500).

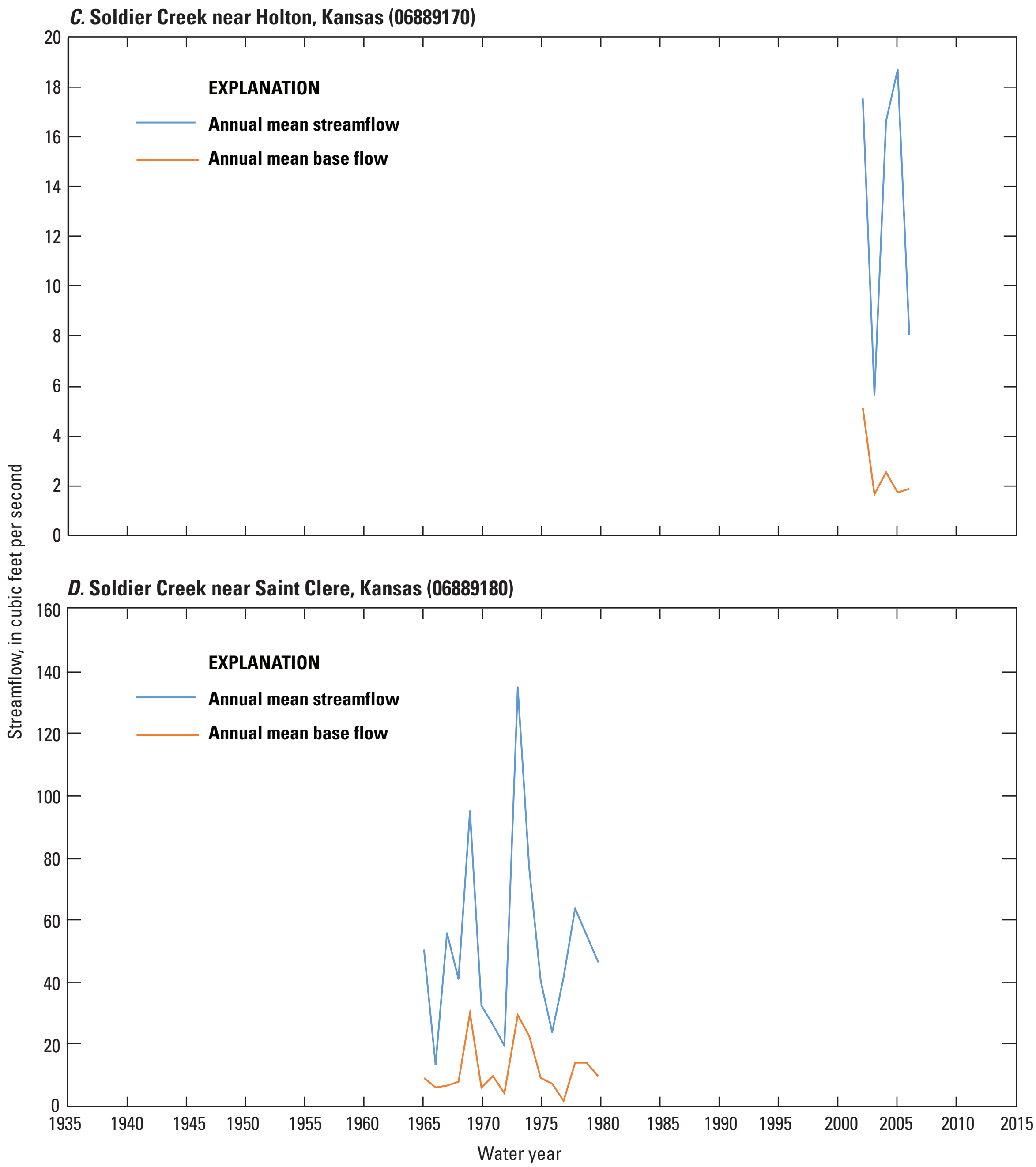

Figure 4. Variation in annual mean streamflow and annual mean base flow at six selected U.S. Geological Survey streamgages. *A*, Soldier Creek near Soldier, Kansas (06889140). *B*, Soldier Creek near Circleville, Kansas (06889160). *C*, Soldier Creek near Holton, Kansas (06889170). *D*, Soldier Creek near Saint Clere, Kansas (06889180). *E*, Soldier Creek near Delia, Kansas (06889200). *F*, Soldier Creek near Topeka, Kansas (06889500).—Continued

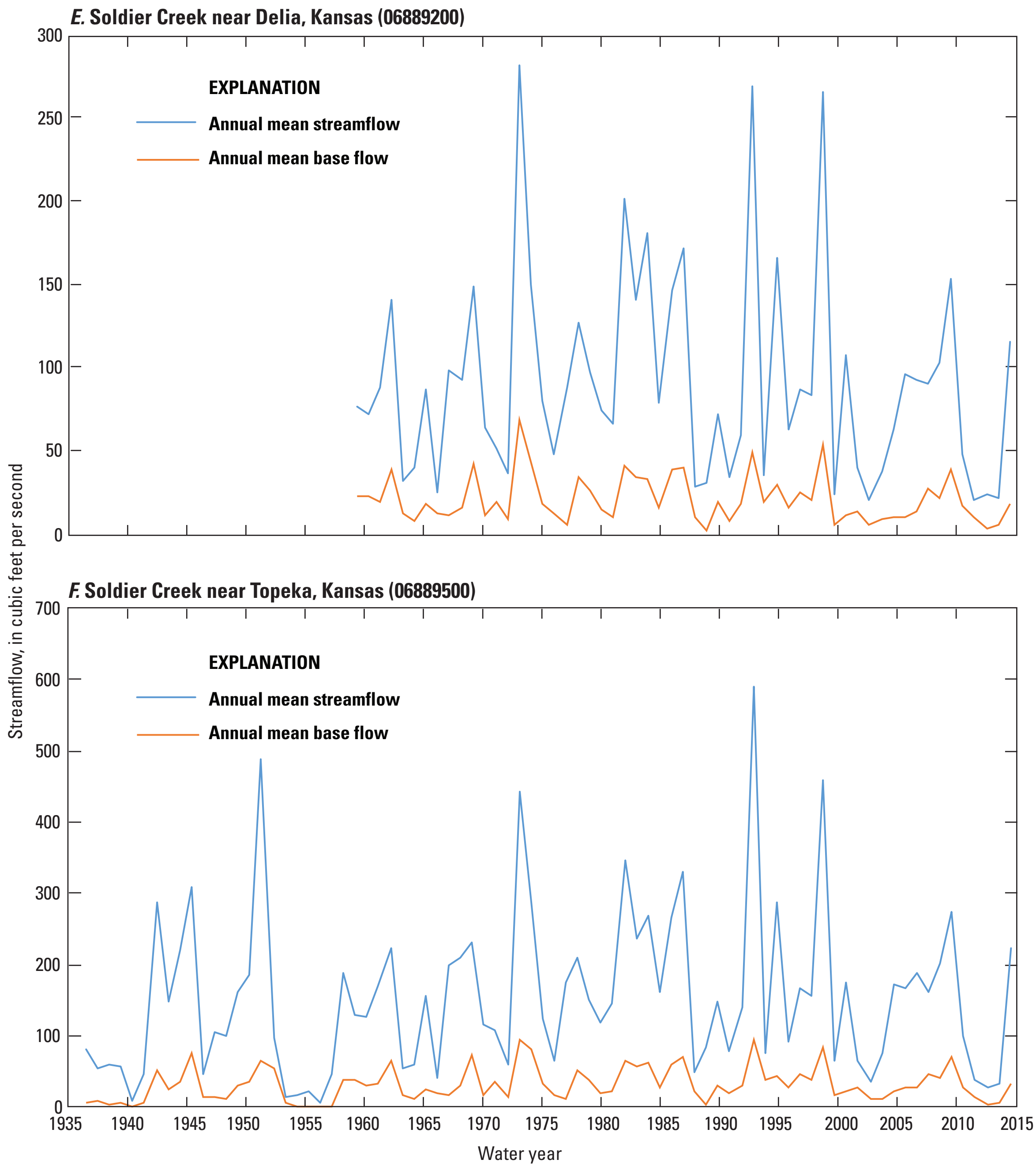

Figure 4. Variation in annual mean streamflow and annual mean base flow at six selected U.S. Geological Survey streamgages. *A*, Soldier Creek near Soldier, Kansas (06889140). *B*, Soldier Creek near Circleville, Kansas (06889160). *C*, Soldier Creek near Holton, Kansas (06889170). *D*, Soldier Creek near Saint Clere, Kansas (06889180). *E*, Soldier Creek near Delia, Kansas (06889200). *F*, Soldier Creek near Topeka, Kansas (06889500).—Continued

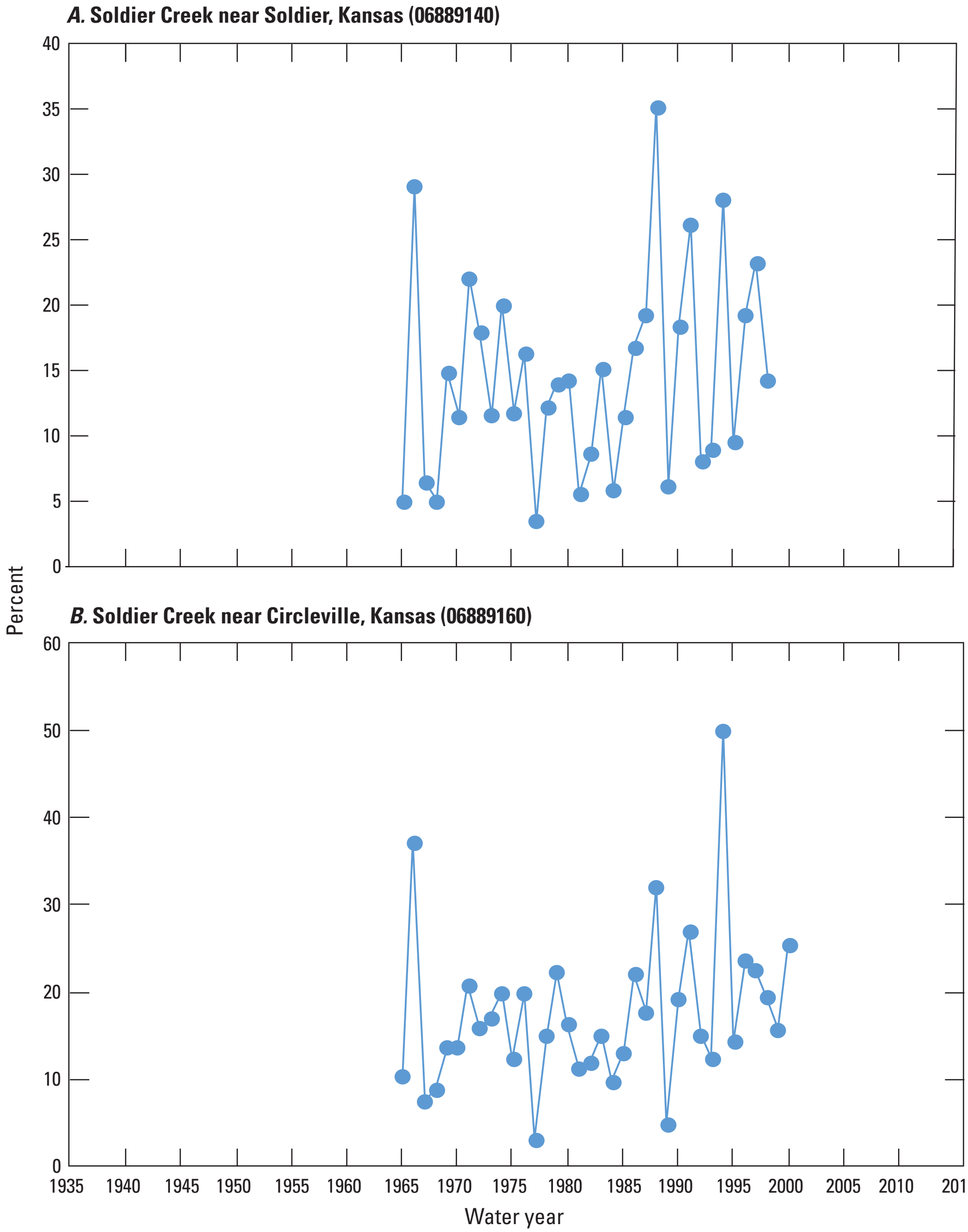

Figure 5. Variation in annual mean base flow as percentage of annual mean streamflow at six selected U.S. Geological Survey streamgages. *A*, Soldier Creek near Soldier, Kansas (06889140). *B*, Soldier Creek near Circleville, Kansas (06889160). *C*, Soldier Creek near Holton, Kansas (06889170). *D*, Soldier Creek near Saint Clere, Kansas (06889180). *E*, Soldier Creek near Delia, Kansas (06889200). *F*, Soldier Creek near Topeka, Kansas (06889500).

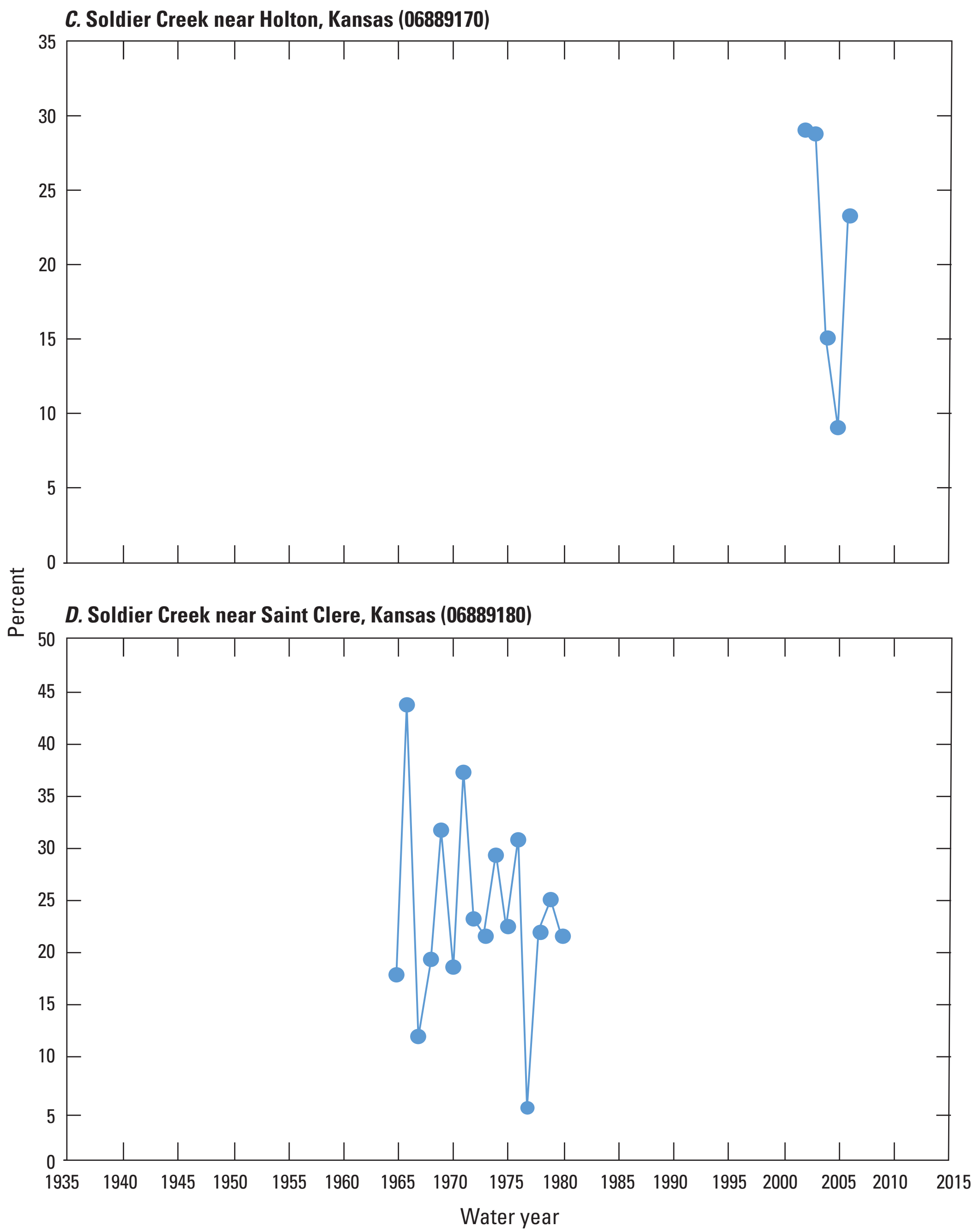

Figure 5. Variation in annual mean base flow as percentage of annual mean streamflow at six selected U.S. Geological Survey streamgages. *A*, Soldier Creek near Soldier, Kansas (06889140). *B*, Soldier Creek near Circleville, Kansas (06889160). *C*, Soldier Creek near Holton, Kansas (06889170). *D*, Soldier Creek near Saint Clere, Kansas (06889180). *E*, Soldier Creek near Delia, Kansas (06889200). *F*, Soldier Creek near Topeka, Kansas (06889500).—Continued

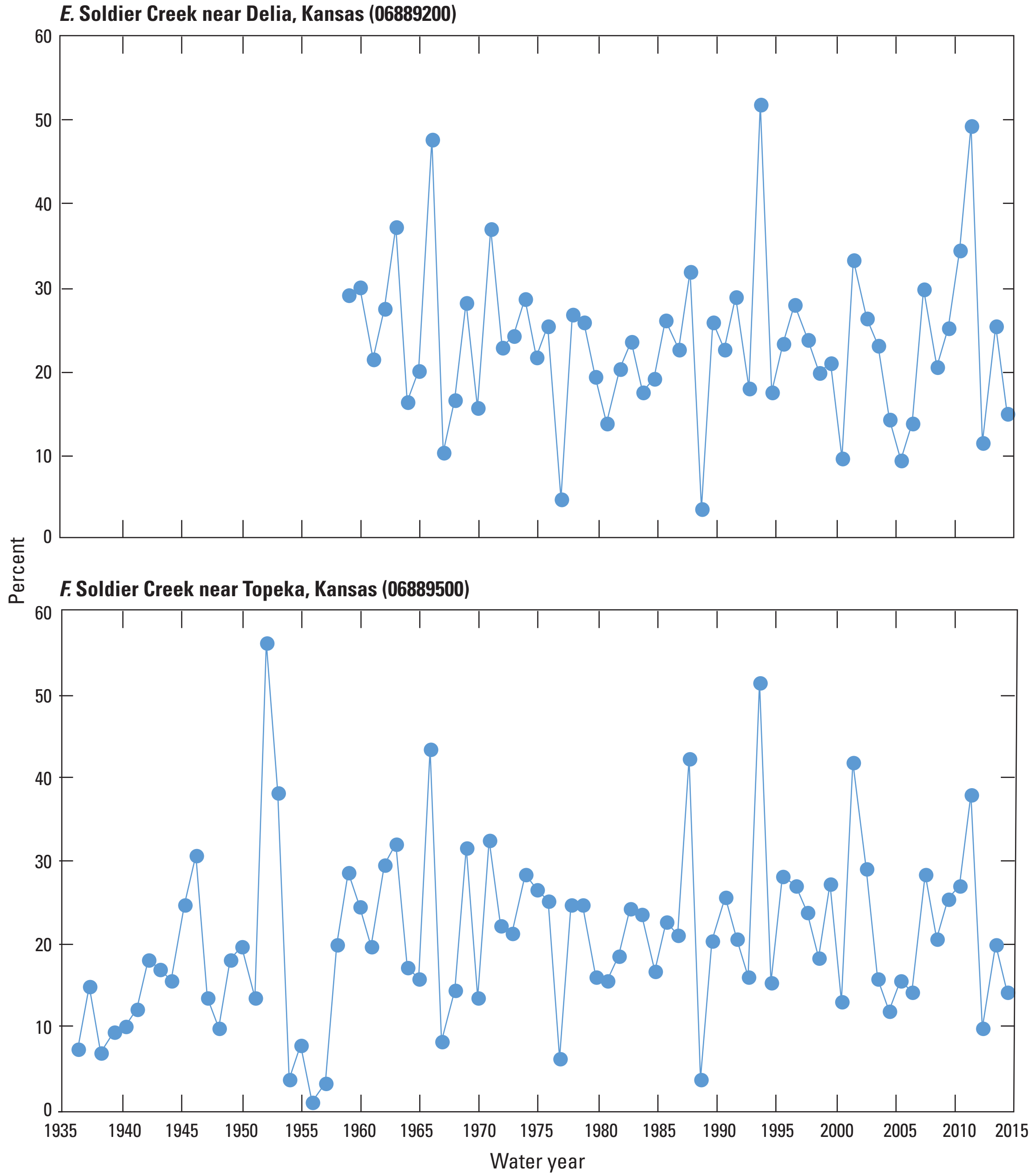

Figure 5. Variation in annual mean base flow as percentage of annual mean streamflow at six selected U.S. Geological Survey streamgages. *A*, Soldier Creek near Soldier, Kansas (06889140). *B*, Soldier Creek near Circleville, Kansas (06889160). *C*, Soldier Creek near Holton, Kansas (06889170). *D*, Soldier Creek near Saint Clere, Kansas (06889180). *E*, Soldier Creek near Delia, Kansas (06889200). *F*, Soldier Creek near Topeka, Kansas (06889500).—Continued

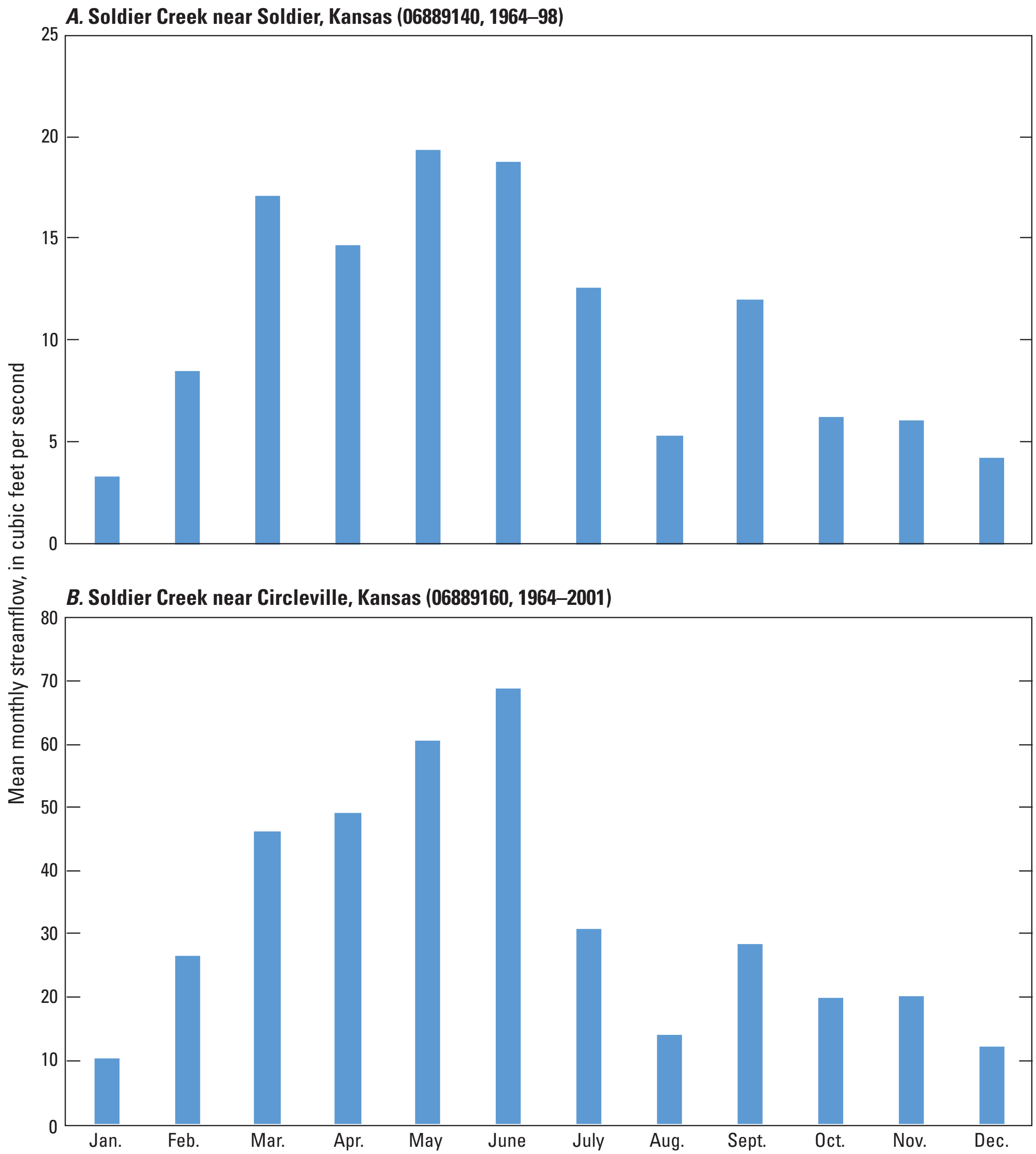

Figure 6. Mean monthly flows for the period of record at six selected U.S. Geological Survey streamgages. *A*, Soldier Creek near Soldier, Kansas (06889140). *B*, Soldier Creek near Circleville, Kansas (06889160). *C*, Soldier Creek near Holton, Kansas (06889170). *D*, Soldier Creek near Saint Clere, Kansas (06889180). *E*, Soldier Creek near Delia, Kansas (06889200). *F*, Soldier Creek near Topeka, Kansas (06889500).

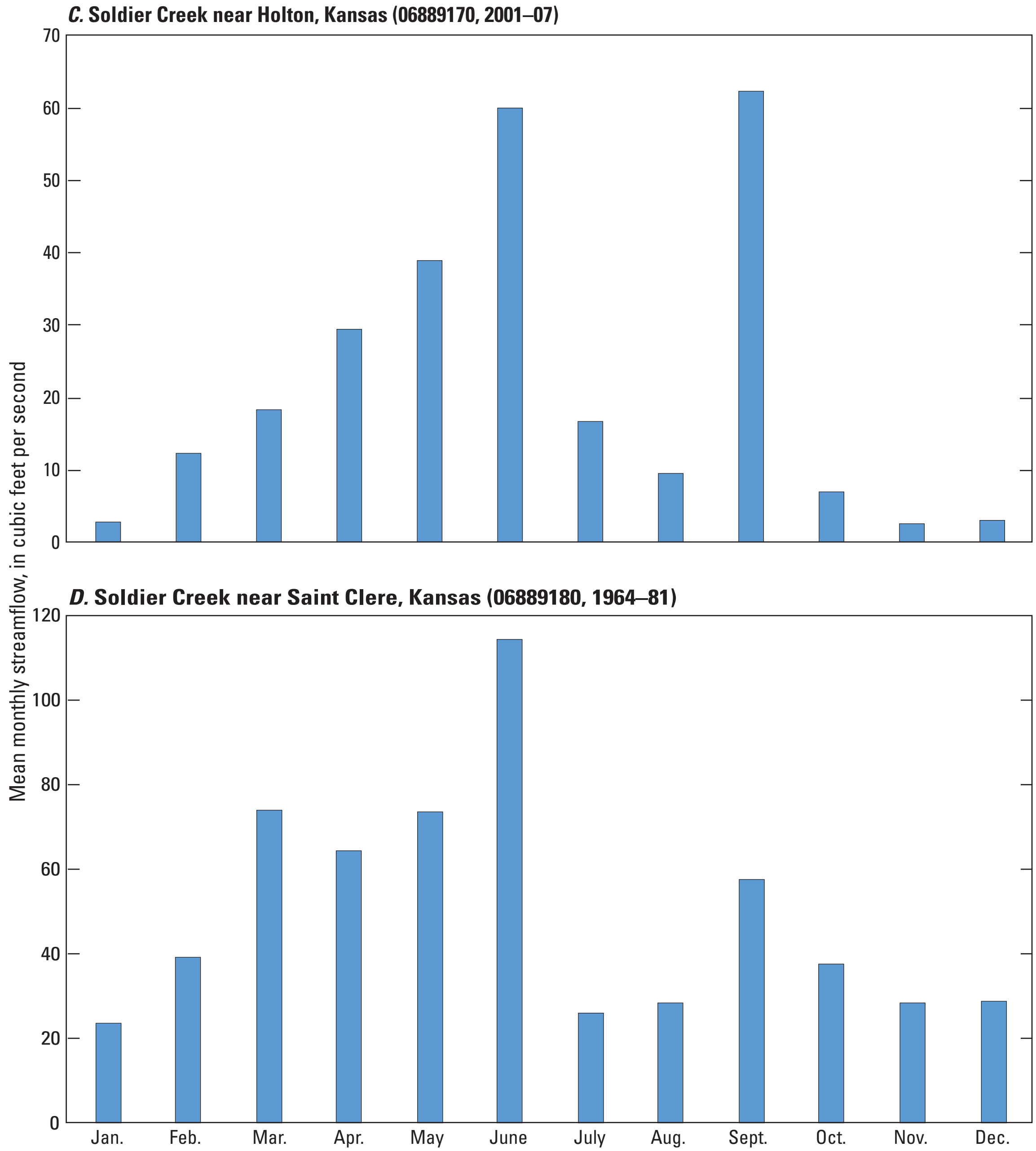

Figure 6. Mean monthly flows for the period of record at six selected U.S. Geological Survey streamgages. *A*, Soldier Creek near Soldier, Kansas (06889140). *B*, Soldier Creek near Circleville, Kansas (06889160). *C*, Soldier Creek near Holton, Kansas (06889170). *D*, Soldier Creek near Saint Clere, Kansas (06889180). *E*, Soldier Creek near Delia, Kansas (06889200). *F*, Soldier Creek near Topeka, Kansas (06889500).—Continued

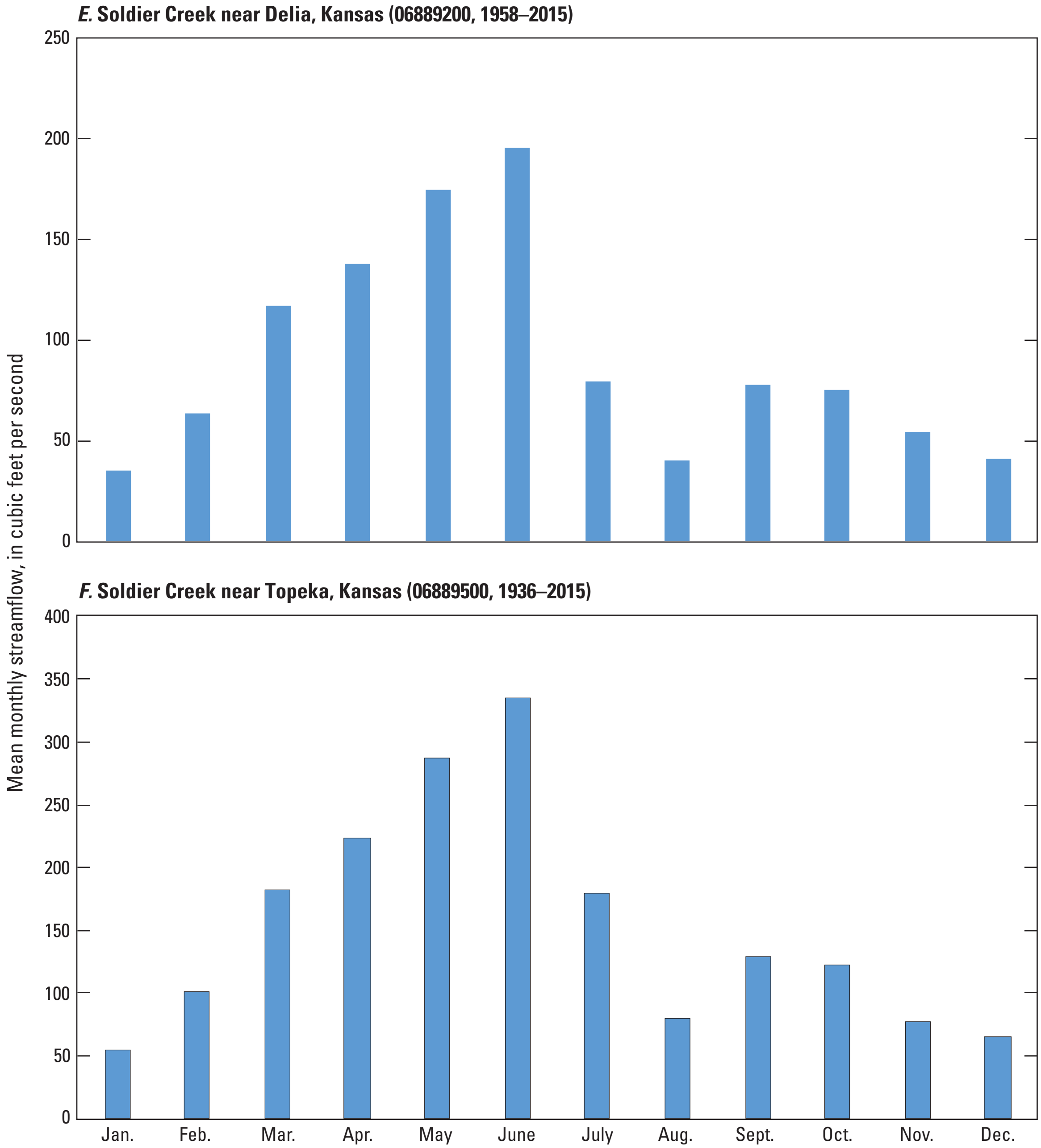

Figure 6. Mean monthly flows for the period of record at six selected U.S. Geological Survey streamgages. *A*, Soldier Creek near Soldier, Kansas (06889140). *B*, Soldier Creek near Circleville, Kansas (06889160). *C*, Soldier Creek near Holton, Kansas (06889170). *D*, Soldier Creek near Saint Clere, Kansas (06889180). *E*, Soldier Creek near Delia, Kansas (06889200). *F*, Soldier Creek near Topeka, Kansas (06889500). —Continued

Annual Peak Flow

With one exception, annual peak flows along Soldier Creek were characterized by considerable year-to-year variability with no pronounced long-term trend (fig. 7). At Soldier, annual peak flows typically (27 of 34 years) were less than 3,000 ft^3/s. However, for 5 years the annual peak was greater than 4,000 ft^3/s. The largest peak of 11,700 ft^3/s occurred in 1970 (fig. 7*A*).

Annual peak flows at Circleville typically (32 of 37 years) were in the range of 2,000 to 6,000 ft^3/s. Notable exceptions occurred in 1982, 1984, and 1999 with respective peaks of 23,900 ft^3/s, 25,300 ft^3/s, and 8,720 ft^3/s (fig. 7*B*). At Saint Clere, year-to-year variability in peak flows was substantial and generally ranged between 1,000 and 8,000 ft^3/s (fig. 7*D*).

Downstream at Delia and Topeka, annual peak flows were characterized by substantial year-to-year variability that apparently increased during the period of record. At Delia, prior to 1980, peak flows varied over the relatively narrow range of about 1,000 to 8,000 ft^3/s. After 1980, peak flows at Delia ranged from about 1,000 to nearly 60,000 ft^3/s and exceeded 15,000 ft^3/s in 5 different years (fig. 7*E*). At Topeka, prior to 1965, peak flows varied over the relatively narrow range of about 1,000 to 11,000 ft^3/s. After 1965, peak flows at Topeka ranged from about 2,000 to nearly 48,000 ft^3/s and exceeded 20,000 ft^3/s in 7 different years (fig. 7*F*). For annual peak flows during the period of record at Topeka (1936 to 2015), a weak ($R^2 = 0.12$) yet statistically significant (p-value $= 0.002$) increasing trend was indicated.

The timing of annual peak flows along Soldier Creek was not restricted to a particular month or season. Inspection of the dates for the annual peak flows for all six streamgages indicated that an annual peak can occur in any month of the year; however, it was determined that annual peaks are most likely to occur in May and June and least likely to occur during November through February.

Annual Minimum Flow

For annual minimum flow, the 1-day, 30-day, and 90-day means were assessed. Similar to the annual peak flows, annual minimum flows along Soldier Creek were characterized by considerable year-to-year variability with no pronounced long-term trend (fig. 8).

At Soldier, the annual 1-day mean minimum flows (hereafter referred to as “1-day minimums”) were, without exception, less than 1 ft^3/s and typically were near zero. The annual 30-day mean minimum flows (hereafter referred to as “30-day minimums”) typically were less than 1 ft^3/s (30 of 34 years). The annual 90-day mean minimum flows (hereafter referred to as “90-day minimums”) frequently were less than 1 ft^3/s (22 of 34 years); however, for 5 years, the 90-day minimum approached or exceeded 4 ft^3/s (fig. 8*A*).

At Circleville, the 1-day minimums generally were less than 1 ft^3/s (28 of 36 years). The 30-day minimums generally ranged between zero and 2 ft^3/s (29 of 36 years). For the 90-day minimums, values mostly ranged between 1 and about 5 ft^3/s (25 of 36 years). Exceptions included 4 years when the 90-day minimum exceeded 10 ft^3/s (fig. 8*B*).

During the relatively short period of record at Saint Clere, annual minimum flows varied substantially. One-day minimums ranged from near zero to about 6 ft^3/s and 30-day minimums ranged from near zero to about 9 ft^3/s. The range for the 90-day minimums was about 1 to about 33 ft^3/s (fig. 8*D*).

At Delia, the 1-day minimums typically were less than 5 ft^3/s (47 of 57 years) and occasionally were less than 1 ft^3/s (22 of 57 years). For 6 years, the 1-day minimum was zero. The 30-day minimums typically were less than 10 ft^3/s (50 of 57 years) and occasionally were less than 2 ft^3/s (19 of 57 years). The 90-day minimums typically were less than 30 ft^3/s (49 of 57 years) and often were less than 10 ft^3/s (29 of 57 years). Conversely, for 7 years the 90-day minimum was greater than 40 ft^3/s and for 3 years it exceeded 70 ft^3/s (fig. 8*E*).

During the period of record at Topeka, 1-day minimums ranged from zero (multiple years in the 1930s through the 1950s) to as much as 20 ft^3/s (in 1982). The 1-day minimums generally were less than 10 ft^3/s (67 of 80 years) and frequently were less than 5 ft^3/s (54 of 80 years). The 30-day minimums generally were less than 20 ft^3/s (69 of 80 years), frequently were less than 10 ft^3/s (52 of 80 years), and sometimes were less than 5 ft^3/s (34 of 80 years). For 7 years the 30-day minimum was zero. The 90-day minimums frequently were less than 30 ft^3/s (58 of 80 years), often were less than 20 ft^3/s (46 of 80 years), and sometimes were less than 10 ft^3/s (32 of 80 years). Conversely, for 9 years the 90-day minimum exceeded 60 ft^3/s and for 2 years (1973 and 1993) it was greater than 150 ft^3/s (fig. 8*F*). Trombley and others (1996), using available daily data for the period 1930 to 1992, determined that the annual 7-day low flow at Topeka most often occurred in August, September, or October.

In the mid-1950s, one of the worst multiyear droughts in Kansas recorded history occurred (Paulson and others, 1991). The effect of the drought on Soldier Creek was recorded at the Topeka streamgage. For 5 consecutive years, 1953 to 1957, the 30-day minimum was zero or nearly zero. In 1957, the 90-day minimum also was zero. In fact, from August 17, 1956, to February 1, 1957, there was zero flow at Topeka for 169 consecutive days. Thus, the streamflow record at Topeka demonstrated that, during an extreme drought, flow in Soldier Creek may be zero continuously for a period of one to several months.

Streamflow-Duration Curves

Streamflow-duration curves show the frequency with which flow of a specified magnitude is equaled or exceeded at a given site over a specified time period and enable a comparison of flow conditions among sites. In this study, flow-duration curves were created to characterize flow conditions at Soldier, Circleville, Saint Clere, Delia, and Topeka (fig. 9,

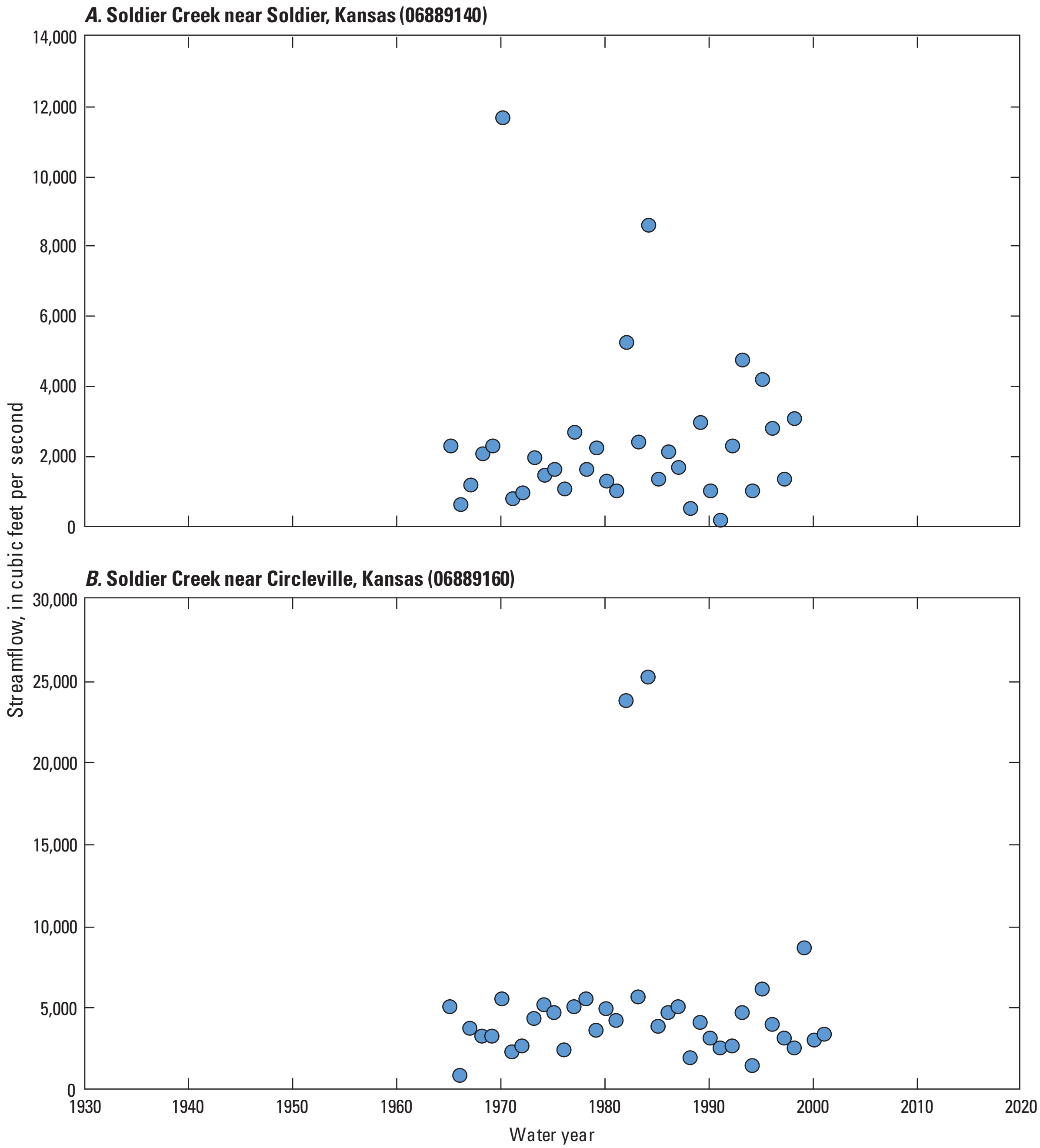

Figure 7. Variation in annual peak flow at six selected U.S. Geological Survey streamgages. *A*, Soldier Creek near Soldier, Kansas (06889140). *B*, Soldier Creek near Circleville, Kansas (06889160). *C*, Soldier Creek near Holton, Kansas (06889170). *D*, Soldier Creek near Saint Clere, Kansas (06889180). *E*, Soldier Creek near Delia, Kansas (06889200). *F*, Soldier Creek near Topeka, Kansas (06889500).

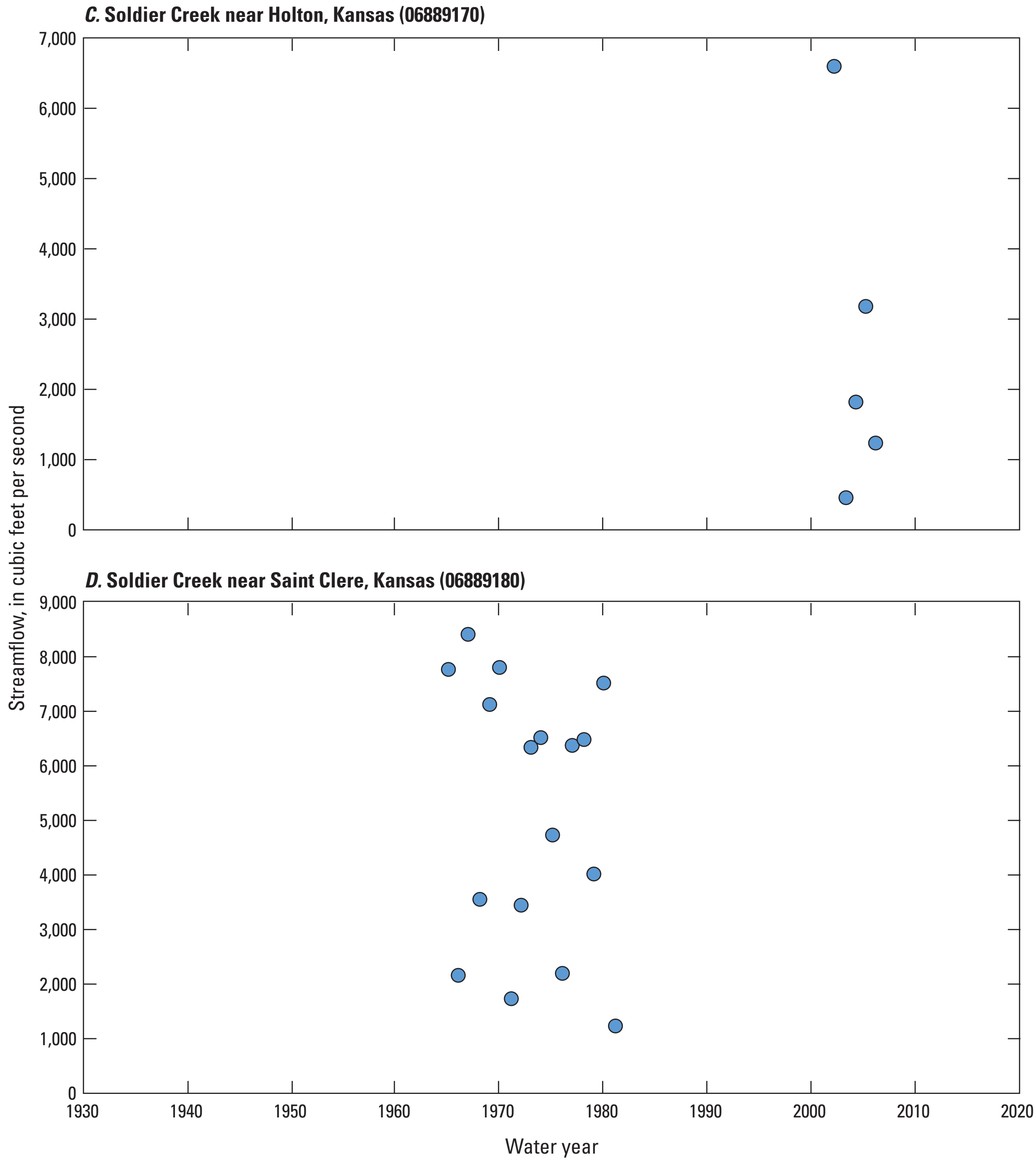

Figure 7. Variation in annual peak flow at six selected U.S. Geological Survey streamgages. *A*, Soldier Creek near Soldier, Kansas (06889140). *B*, Soldier Creek near Circleville, Kansas (06889160). *C*, Soldier Creek near Holton, Kansas (06889170). *D*, Soldier Creek near Saint Clere, Kansas (06889180). *E*, Soldier Creek near Delia, Kansas (06889200). *F*, Soldier Creek near Topeka, Kansas (06889500). —Continued

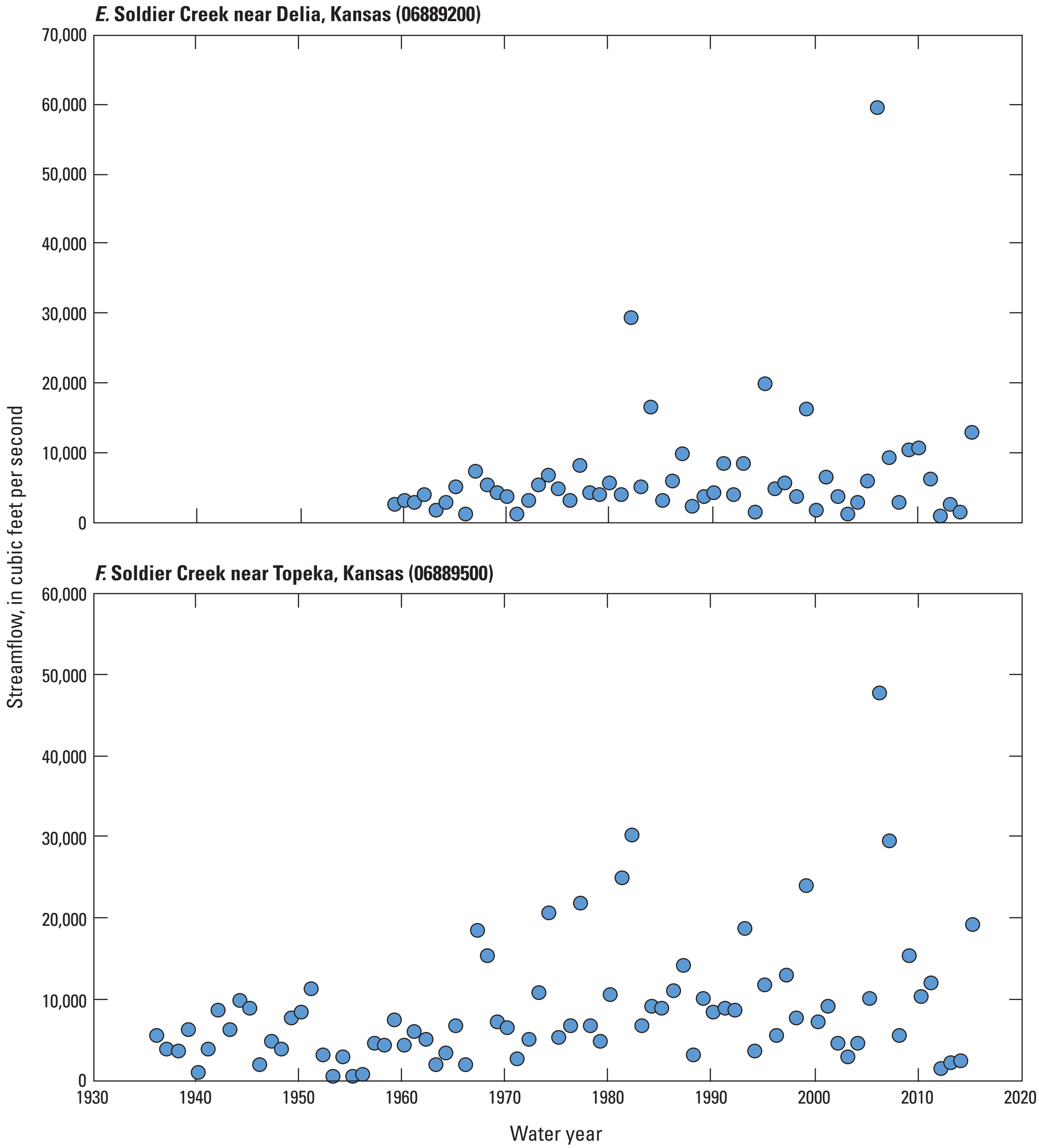

Figure 7. Variation in annual peak flow at six selected U.S. Geological Survey streamgages. *A*, Soldier Creek near Soldier, Kansas (06889140). *B*, Soldier Creek near Circleville, Kansas (06889160). *C*, Soldier Creek near Holton, Kansas (06889170). *D*, Soldier Creek near Saint Clere, Kansas (06889180). *E*, Soldier Creek near Delia, Kansas (06889200). *F*, Soldier Creek near Topeka, Kansas (06889500). —Continued

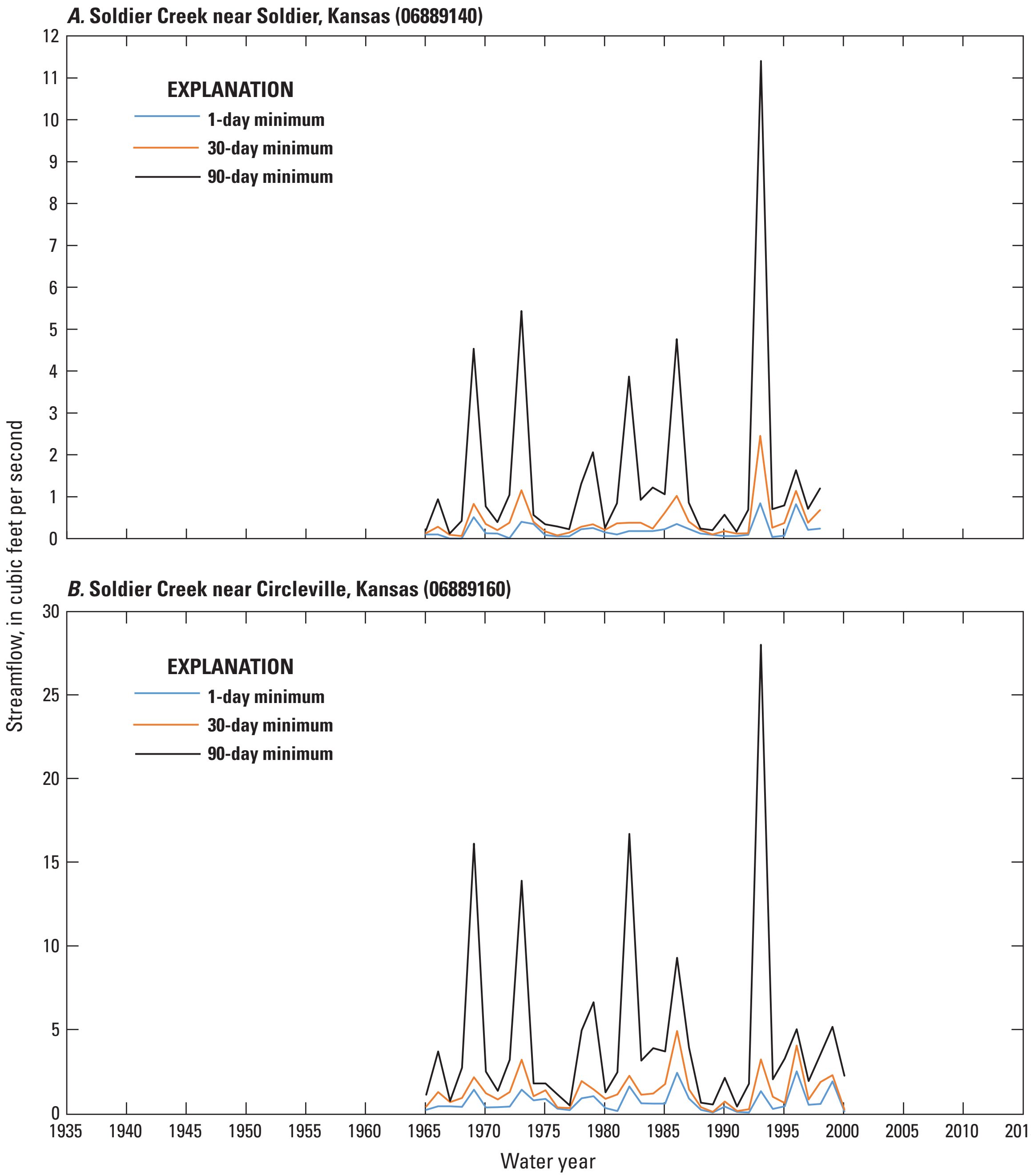

Figure 8. Variation in annual 1-day, 30-day, and 90-day mean minimum flows at six selected U.S. Geological Survey streamgages. *A*, Soldier Creek near Soldier, Kansas (06889140). *B*, Soldier Creek near Circleville, Kansas (06889160). *C*, Soldier Creek near Holton, Kansas (06889170). *D*, Soldier Creek near Saint Clere, Kansas (06889180). *E*, Soldier Creek near Delia, Kansas (06889200). *F*, Soldier Creek near Topeka, Kansas (06889500).

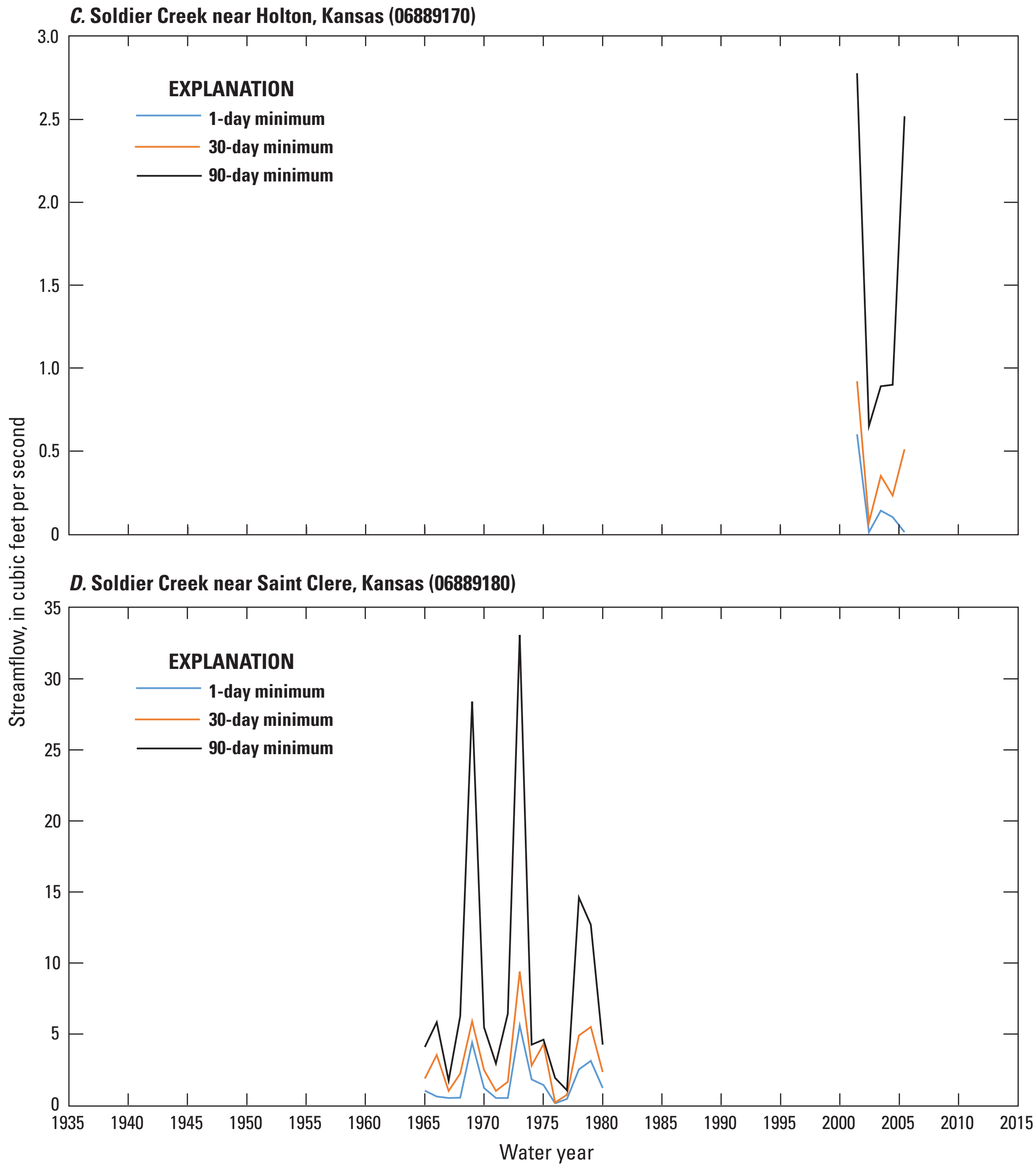

Figure 8. Variation in annual 1-day, 30-day, and 90-day mean minimum flows at six selected U.S. Geological Survey streamgages. *A*, Soldier Creek near Soldier, Kansas (06889140). *B*, Soldier Creek near Circleville, Kansas (06889160). *C*, Soldier Creek near Holton, Kansas (06889170). *D*, Soldier Creek near Saint Clere, Kansas (06889180). *E*, Soldier Creek near Delia, Kansas (06889200). *F*, Soldier Creek near Topeka, Kansas (06889500).—Continued

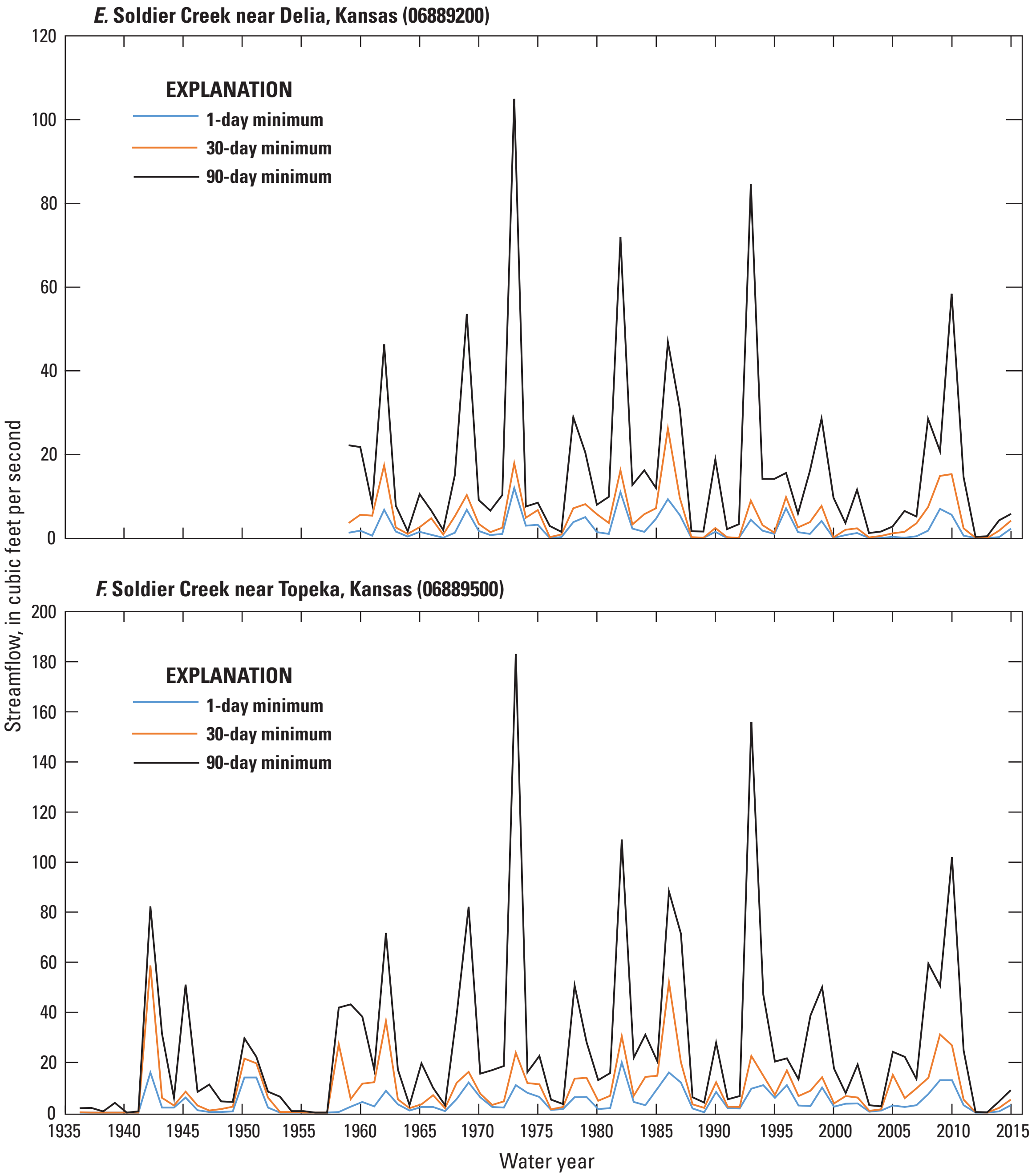

Figure 8. Variation in annual 1-day, 30-day, and 90-day mean minimum flows at six selected U.S. Geological Survey streamgages. *A*, Soldier Creek near Soldier, Kansas (06889140). *B*, Soldier Creek near Circleville, Kansas (06889160). *C*, Soldier Creek near Holton, Kansas (06889170). *D*, Soldier Creek near Saint Clere, Kansas (06889180). *E*, Soldier Creek near Delia, Kansas (06889200). *F*, Soldier Creek near Topeka, Kansas (06889500).—Continued

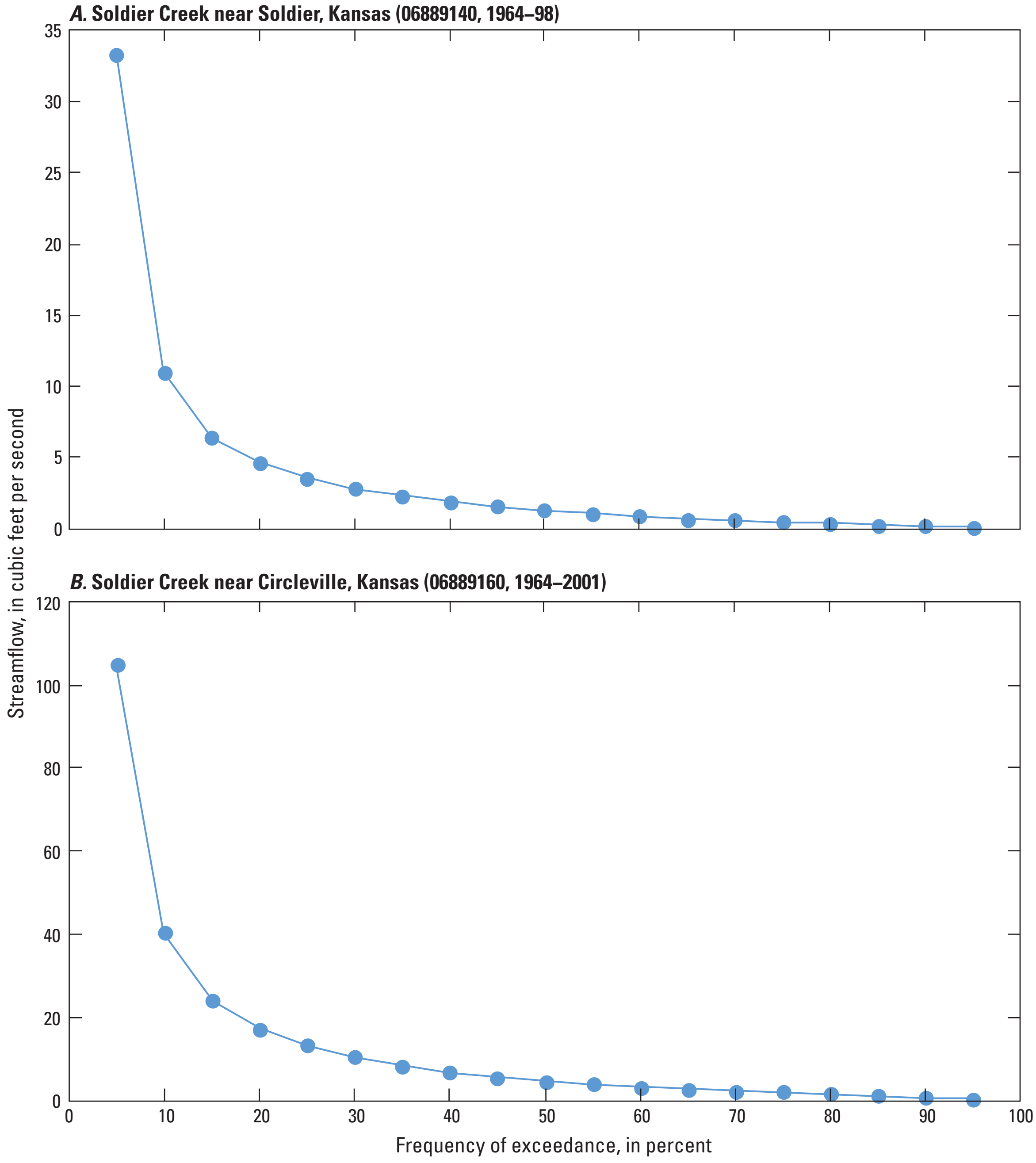

Figure 9. Streamflow-duration curves at five selected U.S. Geological Survey streamgages. *A*, Soldier Creek near Soldier, Kansas (06889140). *B*, Soldier Creek near Circleville, Kansas (06889160). *C*, Soldier Creek near Saint Clere, Kansas (06889180). *D*, Soldier Creek near Delia, Kansas (06889200). *E*, Soldier Creek near Topeka, Kansas (06889500).

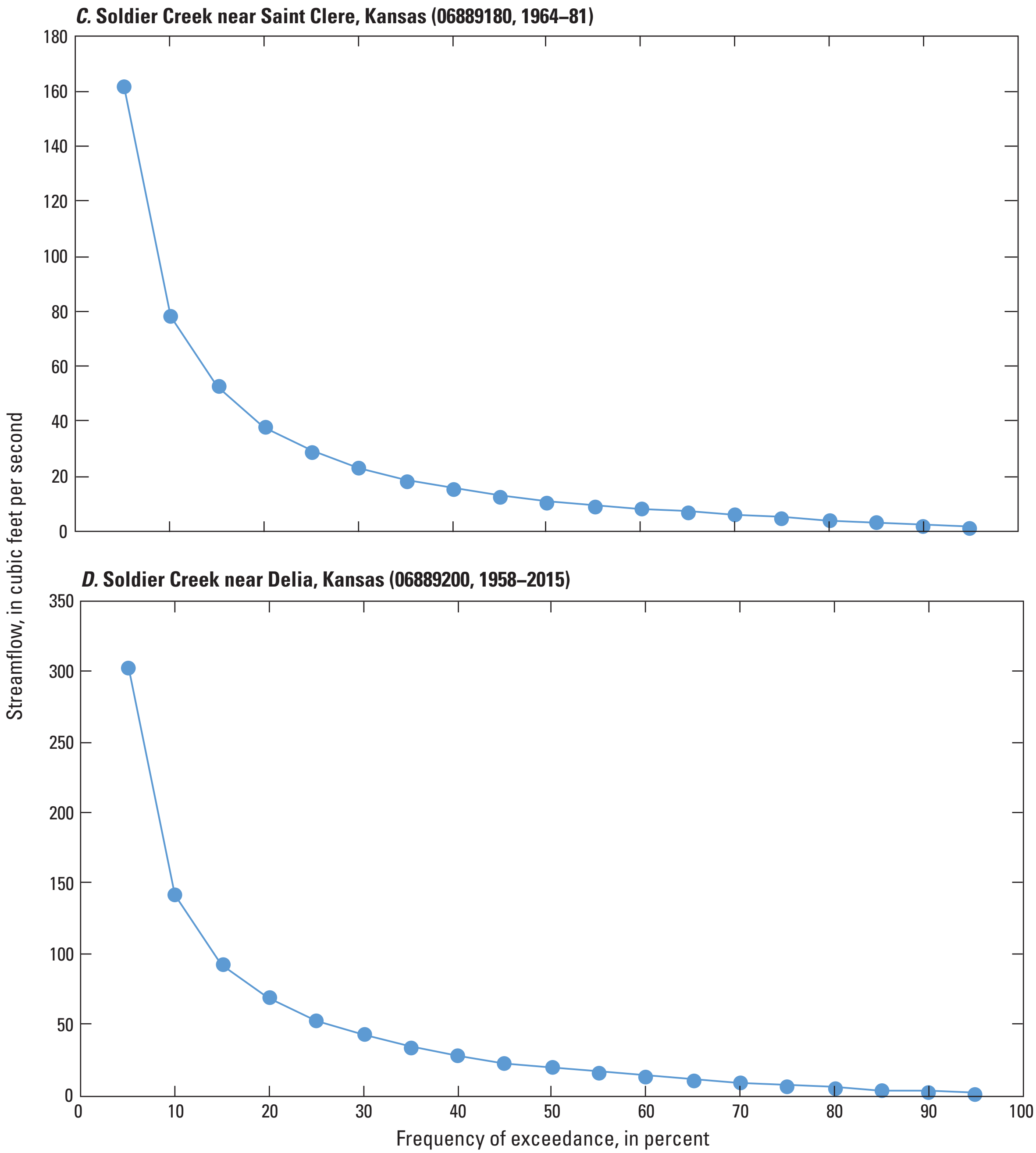

Figure 9. Streamflow-duration curves at five selected U.S. Geological Survey streamgages. *A*, Soldier Creek near Soldier, Kansas (06889140). *B*, Soldier Creek near Circleville, Kansas (06889160). *C*, Soldier Creek near Saint Clere, Kansas (06889180). *D*, Soldier Creek near Delia, Kansas (06889200). *E*, Soldier Creek near Topeka, Kansas (06889500). —Continued

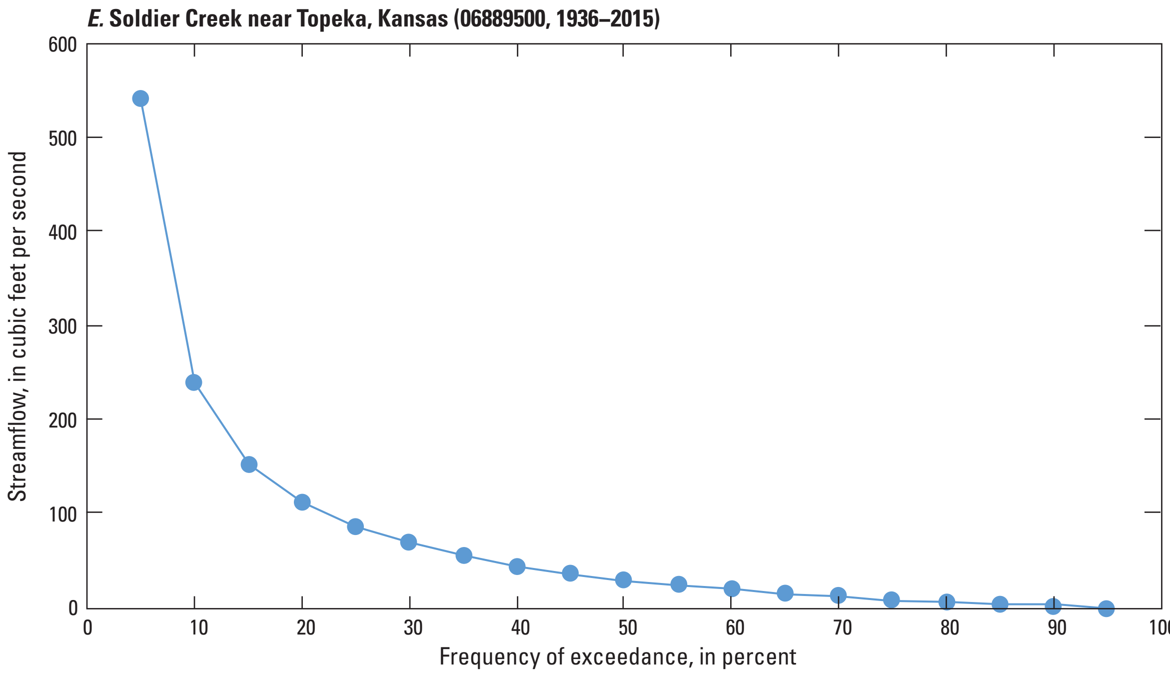

Figure 9. Streamflow-duration curves at five selected U.S. Geological Survey streamgages. *A*, Soldier Creek near Soldier, Kansas (06889140). *B*, Soldier Creek near Circleville, Kansas (06889160). *C*, Soldier Creek near Saint Clere, Kansas (06889180). *D*, Soldier Creek near Delia, Kansas (06889200). *E*, Soldier Creek near Topeka, Kansas (06889500). —Continued

appendix table 1–1). A flow-duration curve was not created for the Soldier Creek near Holton, Kansas, streamgage because the period of record was insufficient for a comparison of values with the other streamgages. For a given frequency of exceedance, the flow-duration curves document the expected increase in flow magnitude with distance downstream along Soldier Creek. For example, the 50-percent exceedance flow increased from about 1 ft^3/s at Soldier to about 30 ft^3/s at Topeka. Between the same two sites, the 10-percent exceedance flow increased from 11 ft^3/s to about 240 ft^3/s (fig. 9).

Summary and Conclusions

A 1-year study by the U.S. Geological Survey, in cooperation with the Prairie Band Potawatomi Nation, was begun in 2016 to provide an assessment of streamflow characteristics and trends at six selected U.S. Geological Survey streamgages along Soldier Creek in northeast Kansas. The intent of the assessment was to provide some of the information needed by the Prairie Band Potawatomi Nation to enable better informed and more effective management of tribal water resources. Results of the assessment are summarized below:

1. Annual mean streamflow was characterized by substantial year-to-year variability with no pronounced long-term trend.

2. The percentage of annual mean streamflow that was annual mean base flow typically ranged from about 5 to 30 percent and averaged about 20 percent.

3. Mean monthly flows were low in January, progressively increased to peak values in May or June, then declined in July and August. Following an increase in September, mean monthly flows again declined in October, November, and December.

4. Annual peak flows, which were characterized by considerable year-to-year variability, were most likely to occur in May and June and least likely to occur during November through February. With the exception of a weak yet statistically significant increasing trend at the Soldier Creek near Topeka, Kansas, streamgage, there were no pronounced long-term trends in annual peak flows.

5. Annual 1-day, 30-day, and 90-day mean minimum flows were characterized by considerable year-to-year variability with no pronounced long-term trend.

6. During an extreme drought, there may be zero flow in Soldier Creek continuously for a period of one to several months.

References Cited

Daly, C., Halbleib, M., Smith, J.I., Gibson, W.P., Doggett, M.K., Taylor, G.H., Curtis, J., and Pasteris, P.P., 2008, Physiographically sensitive mapping of climatological temperature and precipitation across the conterminous United States: International Journal of Climatology, v. 28, p. 2031–2064.

Flynn, K.M., Hummel, P.R., Lumb, A.M., and Kittle, J.L., Jr., 1995, User's manual for ANNIE, version 2, a computer program for interactive hydrologic data management: U.S. Geological Survey Water-Resources Investigations Report 95–4085, 211 p.

Helsel, D.R., and Hirsch, R.M., 1992, Statistical methods in water resources: Amsterdam, Elsevier Science Publishers, 529 p.

Jin, S., Yang, L., Danielson, P., Homer, C., Fry, J., and Xian, G., 2013, A comprehensive change detection method for updating the National Land Cover Database to circa 2011: Remote Sensing of Environment, v. 132, p. 159–175.

National Centers for Environmental Information, 2017, Global Historical Climate Network daily data: accessed March 2017 at http://scacis.rcc-acis.org.

Paulson, R.W., Chase, E.B., Roberts, R.S., and Moody, D.W., 1991, National water summary 1988–89—Hydrologic events and floods and droughts: U.S. Geological Survey Water-Supply Paper 2375, p. 287–294.

Perry, C.A., Wolock, D.M., and Artman, J.C., 2004, Estimates of flow duration, mean flow, and peak-discharge frequency values for Kansas stream locations: U.S. Geological Survey Scientific Investigations Report 2004–5033, 651 p.

Trombley, T.J., Wolf, R.J., Jordan, P.R., and Brewer, L.D., 1996, Overview of water resources in and near Indian lands in northeastern Kansas and southeastern Nebraska: U.S. Geological Survey Water-Resources Investigations Report 96–4070, 68 p.

Turnipseed, D.P., and Sauer, V.B., 2010, Discharge measurements at gaging stations: U.S. Geological Survey Techniques and Methods, book 3, chap. A8, 87 p.

U.S. Geological Survey, 2016, National Water Information System—Web interface: accessed September 28, 2016, at https://dx.doi.org/10.5066/F7P55KJN.

Wahl, K.L., and Wahl, T.L., 1995, Determining the flow of Comal Springs at New Braunfels, Texas: Proceedings, Texas Water '95, American Society of Civil Engineers Symposium, San Antonio, Texas, August 16–17, 10 p.

Walsh, J., Wuebbles, D., Hayhoe, K., Kossin, J., Kunkel, K., Stephens, G., Thorne, P., Vose, R., Wehner, M., Willis, J., Anderson, D., Doney, S., Feely, R., Hennon, P., Kharin, V., Knutson, T., Landerer, F., Lenton, T., Kennedy, J., and Somerville, R., 2014, Our changing climate, chap. 2 *of* Melillo, J.M., Richmond, T.C., and Yohe, G.W., eds., Climate change impacts in the United States—The Third National Climate Assessment: U.S. Global Change Research Program, p. 19–67, accessed March 1, 2016, at http://nca2014.globalchange.gov/.

Glossary

base flow The part of streamflow that is not attributable to direct runoff from precipitation or melting snow. It is usually sustained by groundwater inflow to the stream.

minimum flow The lowest measured streamflow during a period of time (for example, during a year).

peak flow The highest measured streamflow during a period of time (for example, during a year).

period of record The length of time during which data, such as streamflow measurements, were collected.

streamflow The volume of water that passes a given point along a stream per unit time. Synonyms are discharge and flow. A common unit of measurement for streamflow is cubic feet per second.

streamflow-duration curve A curve that shows the percentage of time that a streamflow of specific magnitude is equaled or exceeded during the period of record analyzed.

water year The 1-year period that begins October 1 and ends September 30 and is designated by the calendar year in which the period ends. For example, water year 2016 began on October 1, 2015, and ended on September 30, 2016.

Appendix

Table 1–1. Streamflow duration summarized by frequency of exceedance for the Soldier Creek near Soldier, Kansas (06889140), Soldier Creek near Circleville, Kansas (06889160), Soldier Creek near Saint Clere, Kansas (06889180), Soldier Creek near Delia, Kansas (06889200), and Soldier Creek near Topeka, Kansas (06889500) streamgages.

[USGS, U.S. Geological Survey; %, percent. All streamflow values are in cubic feet per second]

USGS streamgage identifier (fig. 1)	USGS streamgage name	Frequency of exceedance									
		5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
06889140	Soldier Creek near Soldier, Kansas	33.3	11	6.44	4.66	3.6	2.84	2.32	1.91	1.58	1.3
06889160	Soldier Creek near Circleville, Kansas	104.7	40.4	24.1	17.3	13.4	10.5	8.32	6.78	5.61	4.73
06889180	Soldier Creek near Saint Clere, Kansas	161.9	78.2	52.7	37.8	29	23.1	18.5	15.6	12.9	10.8
06889200	Soldier Creek near Delia, Kansas	303.6	142.1	92.4	69.6	53.2	43.1	34.3	28.4	22.8	19.7
06889500	Soldier Creek near Topeka, Kansas	543.6	239.4	152.9	114	86.9	69.4	55.6	45.1	36.8	30.7

USGS streamgage identifier (fig. 1)	USGS streamgage name	Frequency of exceedance								
		55%	60%	65%	70%	75%	80%	85%	90%	95%
06889140	Soldier Creek near Soldier, Kansas	1.08	0.89	0.72	0.6	0.49	0.39	0.3	0.22	0.15
06889160	Soldier Creek near Circleville, Kansas	4.01	3.38	2.89	2.42	2.04	1.64	1.18	0.8	0.52
06889180	Soldier Creek near Saint Clere, Kansas	9.12	8.04	6.96	6.01	5.08	4.03	3.1	2.26	1.39
06889200	Soldier Creek near Delia, Kansas	16.6	13.8	11.3	9.11	7.25	5.44	3.8	2.51	1.36
06889500	Soldier Creek near Topeka, Kansas	24.9	20.7	16.6	13.2	9.71	6.54	4.29	2.27	0.46

Publishing support provided by:
Rolla Publishing Service Center

For additional information concerning this publication, contact:
Director, USGS Kansas Water Science Center
4821 Quail Crest Place
Lawrence, KS 66049
(785) 842–9909

Or visit the Kansas Water Science Center website at:
https://ks.water.usgs.gov

USGS

Juracek—Streamflow Characteristics and Trends Along Soldier Creek, Northeast Kans[as—SIR] 2017–5061

ISSN 2328-0328 (online)
https://doi.org/10.3133/sir20175061